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TECHNICAL REPORT

Military and Civil Defense Nuclear Weapons Effects Projects Conducted at the Nevada Test Site: 1951-1958

May 2011

Barbara Killian

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CONVERSION TABLE

Conversion Factors for U.S. Customary to metric (SI) units of measurement.

MULTIPLY ⟶ BY ⟶ TO GET

TO GET ⟵ BY ⟵ DIVIDE

angstrom	1.000 000 x E -10	meters (m)
atmosphere (normal)	1.013 25 x E +2	kilo pascal (kPa)
bar	1.000 000 x E +2	kilo pascal (kPa)
barn	1.000 000 x E -28	meter^2 (m^2)
British thermal unit (thermochemical)	1.054 350 x E +3	joule (J)
calorie (thermochemical)	4.184 000	joule (J)
cal (thermochemical/cm^2)	4.184 000 x E -2	mega joule/m^2 (MJ/m^2)
curie	3.700 000 x E +1	*giga bacquerel (GBq)
degree (angle)	1.745 329 x E -2	radian (rad)
degree Fahrenheit	$t_k = (t^o f + 459.67)/1.8$	degree kelvin (K)
electron volt	1.602 19 x E -19	joule (J)
erg	1.000 000 x E -7	joule (J)
erg/second	1.000 000 x E -7	watt (W)
foot	3.048 000 x E -1	meter (m)
foot-pound-force	1.355 818	joule (J)
gallon (U.S. liquid)	3.785 412 x E -3	meter^3 (m^3)
inch	2.540 000 x E -2	meter (m)
jerk	1.000 000 x E +9	joule (J)
joule/kilogram (J/kg) radiation dose absorbed	1.000 000	Gray (Gy)
kilotons	4.183	terajoules
kip (1000 lbf)	4.448 222 x E +3	newton (N)
kip/inch^2 (ksi)	6.894 757 x E +3	kilo pascal (kPa)
ktap	1.000 000 x E +2	newton-second/m^2 (N-s/m^2)
micron	1.000 000 x E -6	meter (m)
mil	2.540 000 x E -5	meter (m)
mile (international)	1.609 344 x E +3	meter (m)
ounce	2.834 952 x E -2	kilogram (kg)
pound-force (lbs avoirdupois)	4.448 222	newton (N)
pound-force inch	1.129 848 x E -1	newton-meter (N-m)
pound-force/inch	1.751 268 x E +2	newton/meter (N/m)
pound-force/foot^2	4.788 026 x E -2	kilo pascal (kPa)
pound-force/inch^2 (psi)	6.894 757	kilo pascal (kPa)
pound-mass (lbm avoirdupois)	4.535 924 x E -1	kilogram (kg)
pound-mass-foot^2 (moment of inertia)	4.214 011 x E -2	kilogram-meter^2 (kg-m^2)
pound-mass/foot^3	1.601 846 x E +1	kilogram-meter^3 (kg/m^3)
rad (radiation absorbed dose)	1.000 000 x E -2	**Gray (Gy)
roentgen	2.579 760 x E -4	coulomb/kilogram (C/kg)
shake	1.000 000 x E -8	second (s)
slug	1.459 390 x E +1	kilogram (kg)
torr (mm Hg, 0^0 C)	1.333 22 x E -1	kilo pascal (kPa)

*The Becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s.

**The Gray (Gy) is the SI unit of absorbed dose of ionizing radiation.

Military and Civil Defense Nuclear Weapons Effects Projects Conducted at the Nevada Test Site: 1951-1958

Barbara Germain Killian

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INTRODUCTION

This report is the result of research conducted by the author for a book co-authored with John Hopkins: *Nuclear Weapons Testing at the Nevada Test Site: The First Decade.* The book is now in the pre-publication process by the Defense Threat Reduction Agency. The authors are also planning to make this book available as an electronic book through Kindle and/or Apple web sites. This book is a very useful companion for the reader who desires more information regarding who, what, when, and why the projects were conducted as well as the national/international issues and work site environment under which the projects were conducted.

For the Hopkins/Killian book, Barbara had reviewed all of the 324 projects conducted by the Armed Forces Special Weapons Project (AFSWP) for the Department of Defense (DoD) and the 158 conducted by the Civil Defense Agency (FCDA) on the operations BUSTER-JANGLE thru HARDTACK II. Only some of these projects are described in the Hopkins/Killian book. This technical report represents an attempt to identify and to very briefly describe all of the 482 projects in one document. The descriptions herein focus on only the work that was conducted at the Nevada Test Site (NTS).

Usually, work at the site was just a small, but vital, fraction of the total efforts for a project. It is hoped that the hardy reader or casual browser will develop an appreciation of the tremendous amount of important and exciting work that was conducted at the site during those early years of testing, when our country was on a fast learning curve regarding the effects of nuclear weapons as well as developing a nuclear military capability.

Part I of this report describes the military, Department of Defense's (DoD) projects. Part II describes the civil defense projects that were conducted by the Federal Civil Defense Agency (FCDA) and later by the Office of Civil Defense Mobilization (OCDM).

All of the reports used for this report were obtained from the Defense Threat Reduction Agency's Information Analysis Center (DTRIAC) library at Kirtland Airbase, Albuquerque, NM. This center is a priceless national resource as are its personnel who provided ever willing assistance for which I would not have even thought to request: Byron Ristvet, Dea Hunt, Connie Salas, Priscilla Diolazo, Hanna Benhalim, and Katrin Reliford. Byron's encouragement, enthusiasm, and ability to share his vast test experiences and knowledge were greatly appreciated and essential to the completion of both this report and the aforementioned book. Herb Hoppe provided the DoD classification review of this manuscript. He also diligently identified innumerable editorial faux pas and graciously provided both his time and invaluable suggestions.

PART I. MILITARY, DEPARTMENT OF DEFENSE (DoD) NUCLEAR WEAPONS EFFECTS (NWE) PROGRAMS AND PROJECTS ON NTS OPERATIONS 1951-1958

CHAPTER 1. LISTS AND TABLE OF DoD NWE PROGRAMS AND PROJECTS

Introduction

This Chapter has six sections after this Introduction: one section for each of the 6 atmospheric test operations conducted at the NTS between 1951 and 1958, BUSTER-JANGLE thru HARDTACK II. Operation RANGER, the first nuclear operation at NTS is not discussed.

President Truman approved the use of a portion of the Las Vegas Bombing and Gunnery Range as an atomic test site on January 18. The 5 RANGER weapons development tests were conducted between January 27 and February 6 of 1951. Although the DoD did expose a variety of commercial automobiles (during what was termed OPERATION HOT ROD) on RANGER, the frantic schedule for RANGER did not allow the DoD to mobilize and conduct the types and large numbers of effects experiments that would be characteristic of the later operations.

The six operations sections in this chapter list: the programs and projects conducted; the responsible organization(s); and the Weapont Test (WT) number of the reference report. Following the list, a table is given in each section indicating the tests for that operation on which each project was conducted.

The programs and projects conducted on each operation were identified by sets of numbers. The use of sets of numbers for programs and projects began in the Pacific Proving Grounds with Operation GREENHOUSE. Using a couple of numbers rather than the often long titles of the projects must have greatly simplified communication. During the six operations considered here, the four major groups: [Air Force Special Weapons Project (AFSWP), Los Alamos Scientific Laboratory (LASL), University of California Radiation Laboratory (UCRL) at Livermore, and Federal Civil Defense Agency (FCDA)] that conducted NWE programs were assigned the following numbers for their programs:

OPERATION	AFSWP	LASL	UCRL	FCDA
BUSTER-JANGLE	1-9	10.1-10.10		
TUMBLER-SNAPPER	1-9	10-19		
UPSHOT-KNOTHOLE	1-9	10-19	WithLASL	20-29
TEAPOT	1-9	10-19	20-29	30-39
PLUMBBOB	1-9	10-19	20-29	30-39
HARDTACK II	1-9	10-19	20-29	30-39 FCDA 70-71 OCDM*

[*Office of Civil and Defense Mobilization]

Chapter I-1 only considers the AFSWP programs, 1-9. It does not consider the LASL, UCRL, or FCDA programs. The FCDA programs and projects are addressed in Part II. On

PLUMBOB, the Sandia Test Group conducted some programs for the Atomic Energy Commission that had their own numbers. Also, the Desert Rock military exercises sometimes had program numbers.

Each of the AFSWP programs consisted of one or more projects that were conducted to address the goals of that program during an operation. Table I-1 provides an overview of the programs on each NTS operation and cites how many projects were in each program. A total of 324 projects were documented as being conducted by AFSWP during NTS operations between 1951 and 1958.

Table I-1. DoD NWE Programs on Atmospheric Tests at NTS.

OPERATION	PROGRAM	# PROJECTS
BUSTER	2) Thermal and Nuclear Radiation	7
	3) Blast Effects on Structures and Equipment	3
5 Tests	4) Biomedical	4
	6) Test of Service Equipment and Operations	4
	7) Long-range Detection	5
	8) Supporting Measurements	2
	9) Personnel Shelter Evaluation	2
	Total	**27**
JANGLE	1) Blast and Shock	15
	2) Radiological Phenomena	19
2 Tests	3) Blast Effects on Structures	5
	4) Special Phenomena	5
	6) Test of Service Equipment and Operations	7
	7) Long-range Detection	4
	8) Supporting Measurements	1
	Total	**56**
TUMBLER-SNAPPER	1) Blast Measurements	9
	2) Nuclear Measurements and Effects	3
	3) Structures	3
8 Tests	4) Biomedical	5
	6) Test of Equipment and Operations	5
	7) Long-range Detection	5
	8) Thermal Measurements and Efffects	8
	9) Supporting Measurements	4
	Total	**42**
UPSHOT-KNOTHOLE	1) Blast and Shock Measurements	12
	2) Nuclear Measurements and Effects	4
	3) Structures, Material, and Equipment	28
11 Tests	4) Biomedical	5
	5) Aircraft Structures	3
	6) Test of Service Equipment and Operations	11

	7) Long-range Detection	4
	8) Thermal Measurements and Effects	14
	9) Technical Photography	3
	Total	**82**
TEAPOT 14 Tests	1) Blast Pressure Measurements	13
	2) Nuclear Radiation Effects	11
	3) Effects on Equipment and Structures	10
	5) Aircraft Structures	5
	6) Electromagnetic Effects and Tests of Service Equipment	7
	8) Thermal Radiation Effects	8
	9) Supporting Measurements	3
	Total	**57**
PLUMBBOB 24 Tests	1) Blast and Shock	10
	2) Nuclear Radiation Effects	11
	3) Effects on Structures	8
	4) Biomedical	3
	5) Aircraft Structures	5
	6) Electromagnetic Effects and Tests of Service Equipment	5
	8) Thermal Radiation Effects	4
	9) Support Photography	1
	Total	**47**
HARDTACK II 37 Tests	1) Blast and Shock	1
	2) Nuclear Radiation and Effects	5
	4) Biomedical Effects	2
	6) Tests of Service Equipment and Materials	2
	8) Thermal Radiation and Effects	1
	Total	**11**
	TOTAL # OF PROJECTS	**324**

All of the programs were not conducted on all operations, so there may be missing program numbers in an operation. However, as indicated in Table I-1, AFSWP's programs were fairly consistent throughout the operations considered here. For instance, Program 1 generally consisted of projects that measured some feature of airblast or airblast and ground shock, Program 3 Structures, etc..
However, there were a number of intances where a project would be listed under an unsuspected program number. In Chapter I-2, technical areas are identified. In Chapter I-3, the projects in each technical area are discussed.

A "Program#.Project#" was assigned to each project. However, the project numbers also may not be consecutive. For instance project 2.5 might follow 2.2. Also, letters and/or more numbers might be attached to the project number. For instance a project

might be assigned "1.1a-1". This is probably due to the deletion and/or addition of projects between the planning and execution phases of the operation. For a project that "arrived late" but was similar to an existing project, it was undoubtedly easier to tack on a letter or number rather than continuously change all of the existing project numbers.

The 324 DoD projects are listed by operation in the following Chapters 2 and 3. They are listed for each operation by increasing program number, then by increasing project number for that program number, with the following format:

Program#.Project # -- Title – Organization(s). (WT-#)

The title of each project is given after the Program#.Project#. The titles are often descriptive but can be quite long. In the literature, projects are often referred to simply by their numbers rather than by their long titles. The titles of the projects convey the increased sophistication of many of the projects over time. Instrumentation was constantly being improved, and there was increasing effort placed on comparing measurements with predictions, which were also becoming more sophisticated.

Following the title, the organization(s) that was responsible for conducting the project is cited. Military laboratories conducted over 80% of the 324 DoD AFSWP projects that were conducted during atmospheric testing at NTS. This percent did not change much during the period of atmospheric testing at NTS. However, probably because of its frantic time scale, HARDTACK II had all 11 AFSWP projects conducted by military laboratories. Military laboratories were comprised of both military and civilian personnel. Among the major military laboratories that participated on NTS projects were: Air Force Cambridge Research Center (AFCRC); Air Research and Development Command (ARDC); Air Weather Service(AWS); Army Chemical Center (ACC); Army Signal Corps Engineering Laboratories (SCEL); Ballistics Research Laboratories (BRL); Bureau of Yards and Docks (BYD); David Taylor Model Basin (DTMB); Engineering Research and Development Laboratory (ERDL); Evans Signal Laboratory (ESL); Naval Civil Engineering Research and Evaluation Laboratory (NCEREL); Naval Electronics Laboratory (NEL); Naval Material Laboratory (NML); Naval Medical Research Institute (NMRI); Naval Ordnance Laboratory (NOL); Naval Radiological Defense Laboratory (NRDL); Quartermaster Research and Development Laboratories (QRDL); Wright Air Development Center (WADC); Army Corps of Engineers (ACE); and Walter Reed Army Medical Center (WRAMC).

Other participants on the DoD AFSWP projects included: the Atomic Energy Commission (AEC) laboratories, other government organizations, universities, and private companies. These organizations often conducted projects in cooperation with a military laboratory. The AEC laboratories, Los Alamos, Livermore, and Sandia, conducted about 4% of the AFSWP projects.

Other government organizations such as Public Health Service, the Forest Service, Bureau of Standards; and Agriculture conducted about 6% of the projects. Universities, which included: Stanford Research Institute, University of IL and Armour Research Foundation (ARF), University of VA, MIT, and UCLA, also conducted about 6%.

Only about 1% of the projects were conducted by non-government private organizations. EG&G (Edgerton, Germeshausen, and Grier) was, by far, the most prominent private participant during atmospheric testing.

Weapon Test (WT) reports were written for nearly all of the projects. Following the name of the responsible organization(s), a WT number is given in parentheses when such a report is available. In a few cases, a final WT report does not exist; but an Interim Technical Report (ITR) may exist and is cited. Both the WT number and the Program#.Project# are useful for locating references in various data bases.

Tables I-2 thru I-7 are for the six operations. They indicate the test(s) on which each project was conducted. These tables provide an overview of the scope of the activities that were conducted for each operation and test. Generally, projects that were relatively easy to field were conducted on more tests during an operation than those that required considerable construction or instrumentation. Examples of easy to field projects were those just requiring the mounting of relatively small samples of materials, food stuffs, etc. for exposure or those which tested new equipment for measuring radiation levels. The more complex projects that involved the construction of structures were often just conducted on one test during an operation. Such structures were often purposefully placed in the field where they would be destroyed or significantly damaged during that one test.

The number of projects conducted or the number of times a project was conducted during an operation is not a direct measure of the efforts exerted. However such numbers do provide some insight into the level of effort and the importance, at that time, of those types of measurements.

Each of the operations had a unique "flavor" which was a result of the projects that were being conducted. In addition to serving as a reference for the projects conducted, it is hoped that the lists and tables given next help to provide the reader with some of the "flavor" of each operation.

DoD NWE PROGRAMS AND PROJECTS ON BUSTER-JANGLE:10/22/51 – 11/05/51

In this section, Program#.Project#, title, responsible organization, and the WT report # for the projects conducted during BUSTER and JANGLE are listed. Programs 2 and 4 were different in BUSTER and JANGLE. Program 2 was Thermal and Nuclear Radiation on BUSTER and Radiological Phenomena on JANGLE. Program 4 was Bio-medical on BUSTER and Special Phenomena on JANGLE. Table I-2 lists the projects and indicates the tests on which each project was conducted during both BUSTER and JANGLE.

BUSTER

(Ponton et. al 1982c: 59-75; Jackson 1993: 8-1 to 8-7)

On BUSTER, there was no Program 1.

Program 2) Thermal and Nuclear Radiation

2.2 Thermal and Blast Effects On Idealized Forest Fuels - Division of Fire Research, Forest Service. (WT-309)
2.3 Effects of Geometry on Flash Thermal Damage – Naval Material Laboratory. (WT-310)
2.4a Protective Value and Ignition Hazards of Textile Materials Exposed to Thermal Radiation - Office of the Quartermaster General; Quartermaster Board; Engineer Research and Development Laboratory. (WT-312)
2.4b Thermal Radiation Effects on Paints, Plastics, and Coated Fabrics – Engineer Research and Development Laboratory. (WT-407)
2.4-1 Basic Thermal Radiation Measurements – Naval Radiological Defense Laboratory. (WT-409)
2.4-2 The Effect of Thermal Radiation on Materials – Naval Material Laboratory. (WT-311)
2.6 Protective Effects of Field Fortifications Against Neutron and Gamma Ray Flux Engineer Research and Development Laboratories. (WT-383)

Program 3) Blast Effects on Structures and Equipment

3.5 Minefield Clearance – Engineer Research and Development Laboratories. (WT-313)
3.8 Effects of Atomic Detonation on Aircraft Structures on the Ground – Wright Air Development Center. (WT-384)
3.9 Effects on Selected Water Supply Equipment – Engineer Research and Development Laboratories. (WT-314)

Program 4) Biomedical

4.1 Radiation Dosimetry – Naval Medical Research Institute. (WT-315)
4.2 Thermal Effects on Animals (Dogs) – Medical College of Virginia; Office of the Surgeon General. (WT-362)
4.2a Thermal Effects on Animals (Rats) – Naval Radiological Defense Laboratory. (WT-316)

4.3 Flash Blindness – Air Force School of Aviation Medicine. (WT-341)

Program 6) Test of Service Equipment and Operations

6.1b Evaluation of Dosimetric Materials – Signal Corps Engineering Laboratories; Bureau of Ships. (WT-317)
6.4 Airborne Radiac Evaluation – Bureau of Aeronautics; Wright Air Development Center; Air Research and Development Command. (WT-318)
6.5 Operational Tests of Techniques for Accomplishing Indirect Bomb Damage Assessment (IBDA) – Wright Air Development Center. (WT-344)
6.9 Effects of Atomic Detonations on Radio Propagation – Signal Corps Engineering Laboratories. (WT-319)

Program 7) Long-Range Detection

7.1 Transport of Radiation Debris – Headquarters, Air Force; Air Weather Service. (WT-308)
7.2 Long-Range Light Measurements – 4925th Test Group; EG&G. (WT-379)
7.3 Radiochemical, Chemical, and Physical Analysis of Atomic Bomb Debris – Headquarters, Air Force; 4925th Test Group. (WT-320)
7.5 Seismic Waves from A-Bombs Detonated over a Land Mass – 1009th Special Weapons Squadron; Naval Ordnance Lab; Wright Air Development Center; Coast and Geodetic Survey. (WT-321)
7.6 Airborne Low-frequency Sound from the Atomic Explosions – Naval Electronics Laboratory; Signal Corps Engineering Labs; National Bureau of Standards. (WT-322)

Program 8) Supporting Measurements

8.2 Air Weather Service Participation – 2060th Mobile Weather Squadron, Tinker AFB. (WT-342)
8.4 Technical Photography for IBDA Project – Air Force Lookout Mountain Laboratory.

Program 9) Personnel Shelter Evaluation

9.1a FCDA Family Shelter Evaluation – Federal Civil Defense Administration. (WT-359)
9.1b AEC Communal Shelter Evaluation – Los Alamos Scientific Laboratory, FCDA, AEC. (WT-360)

JANGLE

(Ponton et. al 1982c: 75-106; Jackson 1993: 8-7 to 8-15)

Program 1) Blast and Shock

1.1 Ground Acceleration – Naval Ordnance Laboratory. (WT-388)
1.2a-1 Peak Air Blast Pressures from Shock Velocity – Ballistics Research Laboratories. (WT-323)
1.2a-2 Transient Ground Mechanical Effects from High Explosives and Nuclear Explosives - Ballistics Research Laboratories. (WT-385)
1.2b Close-in Ground Measurements – Naval Special Weapons Unit. (WT-364)
1.3a Free Air Shock Arrival Time – Brookhaven National Laboratory. (WT-324)
1.3b Peak Pressure vs. Distance in Free Air Using Smoke and Rocket Photography – Naval Ordnance Laboratory. (WT-389)
1.3c The Measurement of Free Air Atomic Blast Pressures – Air Force Cambridge Research Center; 6531st Flight Squadron. (WT-325)
1.4 Free Air Pressure Measurements – Sandia Corporation. (WT-306)
1.5a Transient Ground Displacement Measurement – Naval Ordnance Laboratory. (WT-382)
1.5b Detection of Time of Arrival of First Earth Motion - David Taylor Model Basin. (WT-326)
1.6 Earth Displacement (Shear Shafts) – Ohio River Division Laboratories; Office Chief of Engineers. (WT-353)
1.7 Ground Acceleration (Shock Pins) – Massachusetts Institute Of Technology; Office Chief of Engineers. (WT-357)
1(8)-b Air Weather Service Participation in Operation JANGLE – 2060th Mobile Weather Squadron. (WT-361)
1(9)-a Ground Acceleration, Ground and Air Pressures for Underground Tests – Stanford Research Institute. (WT-380)
1(9)-b Base Surge Analysis for Nuclear Tests – Naval Ordnance Laboratory. (WT-390)

Program 2) Radiological Phenomena

2.1a Gamma Radiation as a Function of Time and Distance – Evans Signal Laboratory; National Bureau of Standards. (WT-329)
2.1b Gamma Radiation as a Function of Time with Droppable Telemeters – Naval Air Development Center. (WT-392)
2.1c-1 Aerial Survey of Distant Contaminated Terrain – Headquarters, Air Force. (WT-330)
2.1c-2 Aerial Survey of Local Contaminated Terrain – Bureau of Aeronautics; Air Research and Development Command; Wright Air Development Center. (WT-351)
2.1d Monitor Survey of Ground Contamination - Naval Radiological Defense Laboratory; Radiological Health and Safety Group of LASL; AFSWP. (WT-381)
2.3-1 Total Gamma Radiation Dosage – Evans Signal Laboratory. (WT-331)

2.3-2 Foxhole Shielding of Gamma Radiation – Engineering Research and Development Laboratories. (WT-393)
2.4a Beta Ray and Gamma-Ray Energy of Residual Contamination – Naval Radiological Defense Laboratory. (WT-345)
2.4b Gamma Depth Dose Measurement in Unit-density Material – Naval Medical Research Institute. (WT-332)
2.4c Gamma Ray Spectrum Measurements of Residual Radiation – Brookhaven National Laboratory. (WT-348)
2.5a-1 Airborne Particle Studies - Army Chemical Center. (WT-394)
2.5a-2 Fallout Particle Studies – Naval Radiological Defense Laboratory. (WT-395)
2.5a-3 Radiochemical Studies of Large Particles - Army Medical Service Graduate School. (WT-333)
2.6a Remotely Controlled Sampling Techniques – Evans Signal Laboratory; Coles Signal Laboratory. (WT-334)
2.6c-1 Nature and Distribution of Residual Contamination (soil samples) I - National Institute Of Health; Public Health Service. (WT-386)
2.6c-2 Nature and Distribution of Residual Contamination (soil samples) II – Naval Radiological Defense Laboratory. (WT-397)
2.6c-3 Retrievable Missiles for Remote Ground Sampling – National Institute of Health; Public Health Service. (WT-363)
2.7 Biological Injury from Particle Inhalation – National Institute of Health. (WT-396& WT-372)
2.8 Analysis of Test Site and Fallout Material and Photographic Studies - US Department of Agriculture. (WT-335 & WT-423)

Program 3) Blast Effects on Structures

3.1 Navy Underground and Surface Structures – Bureau of Yards and Docks. (WT-404)
3.2 Army Structures Test– Office, Chief of Engineers; Massachusetts Institute of Technology. (WT-387)
3.3 Air Force Structures – Air Material Command; Armour Research Foundation. (WT-405)
3.28 Structure Instrumentation – Sandia Corporation. (WT-406)
3.29 Engineer Soil Mechanics Test – Naval Civil Engineering Research and Evaluation Laboratory. (WT-336)

Program 4) Special Phenomena

4.1 Aerial Technical Photography – Wright Air Development Center. (WT-354)
4.1a-1 Ground Technical Photography Material Operations – Wright Air Development Center. (WT-398)
4.1a-2 Photographic Analysis – Wright Air Development Center. (WT-346)
4.2 Cratering Effects of Underground-Surface Detonated Atomic Bombs and Influence of Soil Characteristics on Crater – Naval Civil Engineering Research and Evaluation Laboratory. (WT-399)

4.5 Characteristics of Missiles From Underground Nuclear Explosions – Stanford Research Institute. (The "missiles" were objects such as nails, crushed red bricks, highway slabs and walls that were pre-placed and lofted by Uncle.) (WT-338)

Program 6) Tests of Service Equipment and Operations

6.1 Evaluation of Military Radiac Equipment – Evans Signal Laboratory; Bureau of Ships. (WT-337)

6.2 Protection and Decontamination of Land Targets and Vehicles – Naval Radiological Defense Lab; Engineer Research and Development Labs; Army Chemical Center; Office, Chief of Engineers. (WT-400)

6.3-1 Evaluation of Military Individual and Collective Protection Device and Clothing – Army Chemical Center. (WT-401)

6.3-2 Evaluation of Potential Respiratory Hazards Associated with Vehicular Operations in a Radioactively Contaminated Area – Ballistics Research Laboratories; Army Field Forces Board Number 2 Test Team; Army Chemical Center. (WT-402)

6.4 Operational Tests of Techniques for Accomplishing IBDA – Wright Air Development Center. (WT-344)

6.7 Clothing Decontamination and Evaluation of Laundry Methods – 9135th Test Support Unit; Office of the Quartermaster General; Evans Signal Laboratory. (WT-347)

6.8 Evaluation of U.S. Army Field Water Supply Equipment and Operations - Engineer Research and Development Laboratories. (WT-340)

Program 7) Long-range Detection

7.1a Transport of Radiation Debris – Headquarters, Air Force; Air Weather Service. (WT-320)

7.1b Radiochemical, Chemical, and Physical Analysis of Atomic Bomb Debris – Headquarters, Air Force; 4925th Test Group.(WT-320)

7.2 Seismic Waves From A-Bombs Detonated Over a Land Mass – 1009th Special Weapons Squadron; Naval Ordnance Lab; Wright Air Development Center; Coast and Geodetic Survey. (WT-321)

7.3 Airborne Low-Frequency Sound from the Atomic Explosions during Operations BUSTER and JANGLE – Naval Electronics Lab; Signal Corps Engineering Labs; National Bureau of Standards. (WT-322)

Program 8) Supporting Measurements

8.4 Technical Photography for IBDA Project – Air Force Lookout Mountain Laboratory

Table I-2. DoD NWE Projects Conducted on BUSTER-JANGLE Tests. (Ponton et.al 1982c:62,76-77)

PROJECT \ TEST	Able	Baker	Charlie	Dog	Easy	Sugar	Uncle
Program 1) Blast and Shock							
1.1						X	X
1.2a-1						X	X
1.2a-2						X	X
1.2b							X
1.3a						X	X
1.3b						X	X
1.3c						X	
1.4						X	X
1.5a						X	X
1.5b							X
1.6						X	X
1.7						X	X
1(8)-b						X	X
1(9)-a							X
1(9)-b							X
Program 2)	BUSTER Thermal and Nuclear Radiation					JANGLE Radiological Phenomena	
2.1a						X	X
2.1b						X	X
2.1c-1						X	X
2.1c-2						X	X
2.1d						X	X
2.2		X	X	X	X		
2.3		X		X			
2.3-1						X	X
2.3-2						X	X
2.4a		X		X		X	X
2.4b		X		X		X	X
2.4c						X	X
2.4-1	X	X	X	X	X		
2.4-2		X		X			
2.5a-1						X	X
2.5a-2						X	X
2.5a-3						X	X
2.6		X	X	X			
2.6a						X	X
2.6c-1						X	X
2.6c-2						X	X
2.6c-3						X	X
2.7						X	X

2.8						X	X
Program 3) Blast Effects on Structures and Equipment							
3.1							X
3.2							X
3.3							X
3.28							X
3.29							X
3.5		X	X	X	X		
3.8				X	X		
3.9					X		
Program 4)	BUSTER Biomedical					JANGLE Special Phenomena	
4.1		X	X	X	X	X	X
4.1a-1						X	X
4.1a-2						X	X
4.2		X		X		X	X
4.2a		X		X			
4.3		X	X	X			
4.5							X
Program 6) Test of Service Equipment and Operations							
6.1						X	X
6.1b		X	X	X			
6.2						X	X
6.3-1						X	X
6.3-2						X	X
6.4		X	X	X	X		X
6.5				X	X		
6.7						X	X
6.8						X	X
6.9			X	X	X		
Program 7) Long Range Detection							
7.1		X	X	X	X		
7.1a						X	X
7.1b						X	X
7.2		X	X	X	X	X	X
7.3	X	X	X	X	X	X	X
7.5	X	X	X	X	X		
7.6		X	X	X	X		
Program 8) Supporting Measurements							
8.2	X	X	X	X	X		
8.4				X	X		X
Program 9) Personnel Shelter Evaluation							
9.1a		X	X	X			
9.1b		X	X	X	X		

DoD NWE PROGRAMS AND PROJECTS ON TUMBLER-SNAPPER: 04/01/52 – 06/05/52

The projects conducted by the DoD on the eight effects measurements programs, during Operation TUMBLER-SNAPPER are listed below. The tests on which these projects were conducted are indicated in Table I-3.(Ponton et.al.1982b, 75-109; United States Atomic Energy Commission 1969: 27-8; Jackson 1993: 9-1 to 9-9)

Program 1) Blast Measurements

1.1 Measurement of Free-Air Atomic Blast Pressures – Air Force Cambridge Research Center and Rome Air Development Center. (WT-511)
1.2 Air Pressure versus Time – Stanford Research Institute. (WT-512)
1.3 Ground-Level Pressure Measurements – Naval Ordnance Laboratory. (WT-513)
1.4 Air Blast Measurement – Ballistic Research Laboratories. (WT-515)
1.5 Free-Air Pressure Measurements – Naval Ordnance Laboratory. (WT-513)
1.6 Ground Acceleration Measurements – Ballistic Research Laboratories. (WT-516)
1.7 Earth Acceleration versus Time – Stanford Research Institute. (WT-517)
1.9 Pre-Shock Dust – Chemical and Radiological Laboratories of the Army Chemical Center. (WT-519)
1.13 Measurement of Air Blast Pressure versus Time – David Taylor Model Basin. (WT-521)

Program 2) Nuclear Measurements and Effects

2.1 Total Gamma Exposure versus Distance – Signal Corps Engineering Laboratories. (WT-522)
2.2 Gamma Ray Energy Spectrum of Residual Contamination - Signal Corps Engineering Laboratories. (WT-523)
2.3 Neutron Flux and Energy Measurements – Naval Research Laboratories. (WT-524)

Program 3) Structures

3.1 Vulnerability of Parked Aircraft to Atomic Bombs – Wright Air Development Center of Dayton, Ohio LASL, and Naval Radiological Defense Laboratory. (WT-525)
3.3 Blast Damage to Trees- Isolated Conifers – Forest Service, Department of Agriculture. (WT-509)
3.4 Minefield Clearance – Engineer Research and Development Laboratories. (WT-526)

Program 4) Biomedical

4.2 Biomedical Exposure Experiment – Naval Medical Research Institute. (WT-527)
4.3 Biological Effectiveness of Neutron Radiation From Nuclear Weapons – Naval Radiological Defense Laboratory. (WT-528)
4.4 Gamma Depth Dose Measurement in Unit Density Material – Naval Medical Research Institute.(WT-529)
4.5 Flash Blindness – Air Force School of Aviation Medicine, Air Training Command, Brooke Army Medical Center, Strategic Air Command. (WT-530)
4.6 Time Course of Thermal Radiation as Measured by Burns in Pigs – Naval Medical Research Institute, University of Rochester Atomic Energy Project. (WT-531)

Program 6) Test of Equipment and Operations

6.1 Evaluation of Military Radiac {RADIAC (RAdiation Detection, Indication, And Computation} Equipment – Bureau of Ships; Signal Corps Engineering Laboratories. (WT-532)

6.3 Evaluation of a Filtration System for Pressurized Aircraft – Army Chemical Center. (WT-533)

6.4 Operational Tests of Radar and Photographic Techniques for IBDA – Wright Air Development Center: Strategic Air Command. (WT-534)

6.5 Decontamination of Aircraft – Wright Air Development Center; Naval Radiological Defense Laboratory. (WT-535)

6.7 Evaluation of Air Monitoring Instruments – Army Chemical Center. (WT-536)

Program 7) Long-Range Detection

7.1a Electromagnetic Effects from Atomic Explosions – National Bureau of Standards, Air Force Cambridge Research Center, Air Weather Service, and Geophysical Laboratory of University of California at Los Angeles. (WT-537)

7.1b Long Range Light Measurements – EG&G and Headquarters Air Force. (WT-538)

7.2 Detection of Airborne Low-Frequency Sound From Atomic Explosions – Headquarters, Air Force; Signal Corps Engineering Laboratories; National Bureau of Standards. (WT-539)

7.3 Radiochemical and Physical Analysis of Atomic Bomb Debris – Headquarters, Air Force. (WT-540)

7.4 Seismic Waves from A-Bombs Detonated over a Desert Valley – Air Force 1009th Special Weapons Squadron; Coast and Geodetic Survey. (WT-541)

Program 8) Thermal Measurements and Effects

8.1 Effects of Atomic Explosions on Forest Fuels – Forest Service, Department of Agriculture. (WT-506)

8.2 Air Temperatures in the Vicinity of a Nuclear Detonation – Naval Radiological Defense Laboratory. (WT-542)

8.3 Thermal Radiation From a Nuclear Detonation - Naval Radiological Defense Laboratory. (WT-543)

8.3a Thermal Radiation Measurements Using Passive Indicators – Naval Material Laboratory. (WT-544)

8.4 Atmospheric Transmission and Weather Measurements – Naval Material Laboratory. (WT-545)

8.5 Incendiary Effects of Atomic Bomb Tests on Building Sections at Yucca Flat – Forest Products Laboratory of the Forest Service. (WT-510)

8.6 Sound Velocity Changes near the Ground in the Vicinity of an Atomic Explosion – Naval Electronics Laboratory. (WT-546)

8.7 Thermal Radiation Measurement – Department of Engineering University of California at Los Angeles. (WT-565)

Program 9) Supporting Measurements

9.1 Technical and Training Photography – Naval Medical Research Institute; Air Force Lookout Mountain Laboratory; Army Pictorial Service Division; Wright Air Development

Center; 4925th Test Group (Atomic); SAC (Strategic Air Command) 5th and 28th Reconnaissance Technical Squadrons; Signal Corps Engineering Laboratories.
9.2 Air Weather Service Participation – Air Weather Service. (WT-508)
9.4 Effects of Atomic Explosions on the Ionosphere – Signal Corps Engineering Laboratories; 9471st Technical Service Unit. (WT-547)
9.5 Electromagnetic Radiation Over the Radio Spectrum From Nuclear Detonations – Signal Corps Engineering Laboratories; 9467th Technical Service Unit. (WT-548)

Table I-3. DoD NWE Projects Conducted onTUMBLER-SNAPPER Tests. (Ponton et.al 1982c:78)

TEST → PROJECT	**Able**	**Baker**	**Charlie**	**Dog**	**Easy**	**Fox**	**George**	**How**
Program 1) Blast Measurements								
1.1					X			X
1.2	X	X	X	X				
1.3	X	X	X	X				
1.4	X	X		X		X		
1.5	X	X	X	X				
1.6	X	X	X	X				
1.7	X	X	X	X				
1.9	X	X	X	X				
1.13		X	X	X				
Program 2) Nuclear Measurements and Effects								
2.1		X	X	X	X	X	X	X
2.2					X	X	X	X
2.3			X	X				X
Program 3) Structures								
3.1	X	X	X	X				
3.3		X	X	X				
3.4		X	X	X				
Program 4) Biomedical								
4.2			X	X	X			X
4.3			X	X				X
4.4			X	X	X			X
4.5			X	X				
4.6			X	X				
Program 6) Test of Equipment and Operations								
6.1	X	X	X	X	X	X	X	X
6.3					X	X	X	
6.4	X	X	X	X	X	X		
6.5				X	X	X	X	X
6.7						X	X	X
Program 7) Long-range Detection								
7.1			X	X	X	X	X	X
7.1b		X	X	X	X	X	X	X
7.2	X	X	X	X	X	X	X	X
7.3	X	X	X	X	X	X	X	X
7.4		X	X	X	X	X	X	X
Program 8) Thermal Measurements and Effects								
8.1			X	X				
8.2	X	X	X	X				
8.3	X	X	X	X				

8.3a			X					
8.4		X	X	X				
8.5			X	X				
8.6	X	X	X	X				
8.7						X	X	X
Program 9) Supporting Measurements								
9.1	X	X	X	X	X	X	X	X
9.2	X	X	X	X	X	X	X	X
9.4	X	X	X	X	X	X	X	X
9.5		X	X	X	X	X	X	

DoD NWE PROGRAMS AND PROJECTS ON UPSHOT-KNOTHOLE: 3/17/53 – 6/04/53

The projects conducted on the DoD's seven effects measurements programs during Operation UPSHOT-KNOTHOLE are listed below. The tests on which they were conducted are cited in Table I-4. (Ponton et.al.1982a, 81-128; United States Atomic Energy Commission 1969: 30-33; Jackson 1993: 11-1 – 11-16)

Program 1) Blast and Shock Measurements

1.1a & 1.2 Air Blast Measurements - Naval Ordnance Laboratory. (WT-710)
1.1a-1 Evaluation of Wiancko and Vibrotron Gauges and Development of New Circuitry for Atomic Blast Measurements – Naval Ordnance Laboratory. (WT-784)
1.1a-2 Development of Mechanical Pressure-Time and Peak Pressure Recorders for Atomic Blast Measurements -- Naval Ordnance Laboratory. (WT-785)
1.1b Air Pressure and Ground Shock Measurements - Stanford Research Institute. (WT-711)
1.1c-1 Air Shock Pressure-Time versus Distance From A Tower Shot - Sandia Corporation; Ballistics Research Laboratories; Naval Ordnance Laboratory. (WT-712)
1.1c-2 Air Shock Pressures As Affected By Hills and Dales – Sandia Corporation. (WT-713)
1.1d Dynamic Pressure Versus Time and Supporting Air Blast Measurements – Sandia Corporation. (WT-714)
1.3 Free-Air Atomic Blast Pressure Measurements - Air Force Cambridge Research Center. (WT-715
1.4a & b Free-Field Measurements Of Earth Stress, Strain, and Ground Motion – Sandia Corporation. (WT-716)
1.5 Test Proceedures and Instrumentation for Projects 1.1c-1, 1.1c-2, 1.1d, 1.4a & b – Sandia Corp..(WT-787)

Program 2) Nuclear Measurements and Effects

2.1 Radioactive Particle Studies Inside An Aircraft – Chemical and Radiological Laboratories. (WT-717)
2.2a Gamma Radiation Spectrum of Residual Contamination – Signal Corps Engineering Laboratories. (WT-718)
2.2b Residual Ionizing Radiation Depth Dose Measurements in Unit-Density Material – Naval Medical Research Institute. (WT-719)
2.3 Neutron Flux Measurements – Naval Research Laboratory. (WT-524)

Program 3) Structures, Material, and Equipment

3.1 Tests On the Loading Of Building and Equipment Shapes – Air Material Command; Armour Research Foundation. (WT-721)
3.1u Shock Diffraction in the Vicinity of a Structure – Naval Ordnance Laboratory. (WT-786)
3.3 Test On The Loading of Horizontal Cylindrical Shapes – Air Material Command; Armour Research Foundation. (WT-722)
3.4 Tests On The Loading of Truss Systems Common To Open-Framed Structures – Air Material Command; Armour Research Foundation. (WT-723)
3.5 Tests on the Response of Wall and Roof Panels and the Transmission of Load to Supporting Structure - Air Material Command; Armour Research Foundation. (WT-724)

3.6 Tests on the Loading and Response of Railroad Equipment– Army Transportation Corps; Air Material Command; Armour Research Foundation. (WT-725)
3.7 Air Blast Effects On Entrances and Air Intakes of Underground Installations – Office, Chief of Engineers, U.S. Army; Structural Research Laboratory, University of Illinois; Ballistic Research Laboratories. (WT-726)
3.8 Air Blast Effects on Entrances of Underground Installations – Office, Chief of Engineers, U.S. Army; Structural Research Laboratory, University of Illinois; Ballistics Research Laboratories. (WT-727)
3.9 Field Fortifications – Engineer Research and Development Laboratories; 412th Engineer Construction Battalion; Naval Ordnance Laboratory; Naval Material Laboratory; Naval Radiological Defense Laboratory; Ballistic Research Laboratories; Signal Corps Engineering Laboratories. (WT-728)
3.11-3.16 Navy Structures - Navy Bureau of Yards and Docks; Naval Civil Engineering Research and Evaluation Laboratory; Stanford Research Institute; Ballistic Research Laboratories; Naval Ordnance Laboratory; Public Building Service; Army Signal Corps; AFSWP. (WT-729)
3.18 Minefield Clearance – Engineer Research and Development Laboratories; 412th Engineer Construction Battalion; 44th Infantry Division. (WT-730)
3.19 Blast Damage to Coniferous Tree Stands by Atomic Explosions – Forest Service. (WT-731)
3.20 Blast and Thermal Effects of an Atomic Bomb on Typical Tactical Communication Systems – Signal Corps Engineering Laboratories; 16th Signal Service Battalion (Corps), Detachment A; 412th Engineer Construction Battalion; Lookout Mountain Laboratory; Coles Signal Laboratory. (WT-732)
3.21 Statistical Estimation of Damage to Ordnance Equipment Exposed to Nuclear Blasts – Ballistic Research Laboratories. (WT-733 and WT-821)
3.22 Effects of Engineering Bridging Equipment – Engineer Research and Development Laboratories. (WT-734)
3.24 Effects of an Airburst Atomic Explosion on Landing Vehicles Tracked (LVT) - Naval Radiological Defense Laboratory. (WT-735)
3.26 Test of the Effects on Petroleum, Oil, and Lubricants (POL) Installations - Air Material Command; Armour Research Foundation; Office of the Quartermaster General; Marine Corps Schools. (WT-736)
3.27 Effects of Atomic Explosions on Field Medical Installations Equipment – Brooke Army Medical Center. (WT-737)
3.28.1 Structures Instrumentation – Ballistic Research Laboratories. (WT-738)
3.28.2 Pressure Measurements for Various Projects in Structures, Material, and Equipment Program – Naval Ordnance Laboratory. (WT-739)
3.28.3 Pressure Measurements on Structures – Stanford Research Institute. (WT-740)
3.29 Blast Effects of Atomic Weapons upon Curtain Walls and Partitions of Masonry and Other Materials - Federal Civil Defense Administration. (WT-741)
3.30 Air Blast Gauge Studies – Ballistic Research Laboratories. (WT-742)

Program 4) Biomedical

4.1 The Radiation Hazard to Personnel within an Atomic Cloud – Air Force Cambridge Research Center; Air Force School of Aviation Medicine; 3205th Drone Group; 4925th Test Group. (WT-743)
4.2 Direct Air Blast Exposure Effects in Animals – Naval Medical Research Institute. (WT-744)
4.5 Ocular Effects of Thermal Radiation from Atomic Detonation – Air Force School of Aviation Medicine. (WT-745)
4.7 Beta-Gamma Skin Hazard in the Postshot Contaminated Area – Walter Reed Army Medical Center. (WT-746)
4.8 The Biological Effects of Neutrons - Naval Radiological Defense Laboratory. (WT-747)

<u>Program 5) Aircraft Structures</u>
5.1 Atomic Weapon Effects on AD Type Aircraft in Flight – Navy Bureau of Aeronautics. (WT-748)
5.2 Atomic Weapon Effects on B-50 Type Aircraft in Flight – Wright Air Development Center. (WT-749)
5.3 Blast Effects on B-36 Type Aircraft in Flight – Wright Air Development Center; Strategic Air Command. (WT-750)

<u>Program 6) Test On Service Equipment and Operations</u>
6.2 IBDA Phenomena and Techniques – Wright Air Development Center; Vitro Corporation. (WT-751)
6.3 Interim IBDA Capabilities of Strategic Air Command – Strategic Air Command. (WT-752)
6.4 Evaluation of Chemical Dosimeters – Chemical and Radiological Laboratories. (WT-753)
6.7 Measurements and Analysis of Electromagnetic Radiation from Nuclear Detonations – Signal Corps Engineering Laboratories. (WT-754)
6.8 Evaluation of Military Radiac Equipment – Signal Corps Engineering Laboratories; Bureau of Ships. (WT-755)
6.8a Initial Gamma Exposure versus Distance-- Signal Corps Engineering Laboratories. (WT-756)
6.9 Evaluation of Naval Airborne Radiac Equipment – Naval Bureau of Aeronautics. (WT-757)
6.10 Evaluation of Rapid Aerial Radiological Survey - Signal Corps Engineering Laboratories. (WT-758)
6.11 Indoctrination of Tactical Air Command Air Crews in the Delivery and Effects of Atomic Weapons – Tactical Air Command; Air Research and Development Command. (WT-759)
6.12 Determination of Height of Burst and Ground Zero – Signal Corps Engineering Laboratories; Army Field Forces Board #1. (WT-760)
6.13 Effectiveness of Fast Scan Radar for Fireball Studies and Weapons Tracking – Naval Electronics Laboratory. (WT-761)

<u>Program 7) Long-range Detection</u>
7.1 Electromagnetic Effects from Nuclear Explosions – Headquarters, Air Force; National Bureau of Standards; Air Force Security Service; Air Force Cambridge Research Center; Air Weather Service. (WT-762)

7.3 Detection of Airborne Low Frequency Sound from Nuclear Explosions – Headquarters, Air Force; Signal Corps Engineering Laboratories; Naval Electronics Laboratory; Bureau of Standards. (WT-763)
7.4 Seismic Measurements – Headquarters, Air Force. (WT-764)
7.5 Calibration and Analyses of Close-in A-Bomb Debris – Headquarters, Air Force, AFSWC. (WT-765)

Program 8) Thermal Measurements and Effects
8.1a Effects of Thermal and Blast Forces From Nuclear Detonations on Basic Aircraft Structures and Components – Wright Air Development Center, Division of Research, University of Dayton. (WT-766)
8.1b Additional Data on the Vulnerability of Parked Aircraft to Atomic Bombs – Wright Air Development Center. (WT-809)
8.2 Measurement of Thermal Radiation With a Vacuum Microphone – Air Force Cambridge Research Center. (WT-767)
8.4.1 Protection Afforded by Operational Smoke Screens Against Thermal Radiation – Army Chemical Center; Naval Radiological Defense Laboratory. (WT-768)
8.4.2 Evaluation of a Thermal Absorbing Carbon Smoke Screen - Army Chemical Center; Naval Radiological Defense Laboratory. (WT-769)
8.5 Thermal Radiation Protection Afforded Test Animals by Fabric Assemblies – Quartermaster Research and Development Laboratories; Walter Reed Army Medical Center. (WT-770)
8.6 Performance Characteristics of Clothing Materials Exposed to Thermal Radiation – Naval Material Laboratory. (WT-771)
8.9 Effects of Thermal Radiation on Materials – Naval Material Laboratory. (WT-772)
8.10 Physical Characteristics of Thermal Radiation from an Atomic Bomb Detonation – Naval Radiological Defense Laboratory. (WT-773)
8.11a Incendiary Effects on Building and Interior Kindling Fuels – Forest Service, Forest Products Laboratory. (WT-774)
8.11b Ignition and Persistent Fires Resulting from Atomic Explosions – Exterior Kindling Fuels - Forest Service, Forest Products Laboratory. (WT-775)
8.12a Sound Velocities Near the Ground in the Vicinity of an Atomic Explosion – Naval Electronics Laboratory. (WT-776)
8.12b Supplementary Pressure Measurements – David Taylor Model Basin. (WT-777)
8.13 Study of Fire Retardant Paints – Engineer Research and Development Laboratories; Bureau of Yards and Docks. (WT-778)

Program 9) Technical Photography
9.1 Technical Photography – EG&G; Signal Corps Pictorial Center; Air Force Lookout Mountain Laboratory. (WT-779)
9.6 Production Stabilization – Waterways Experiment Station; Engineer Research and Development Laboratories; Ohio River Division. (WT-780)
9.7 Experimental Soil Stabilization – Waterways Experiment Station; Engineer Research and Development Laboratories; Ohio River Division. (WT-781)

Table I-4. DoD NWE Projects Conducted on UPSHOT-KNOTHOLE Tests.(Ponton et.al 1982a:83-4)

TEST → / PROJECT	ANNIE	NANCY	RUTH	DIXIE	RAY	BADGER	SIMON	ENCORE	HARRY	GRABLE	CLIMAX
Program 1) Blast and Shock Measurements											
1.1a &1.2	X			X				X		X	X
1.1a-1								X		X	
1.1a-2								X	X	X	
1.1b			X	X				X		X	X
1.1c-1	X						X				
1.1c-2							X				
1.1d								X		X	X
1.3				X				X			
1.4a & b	X							X		X	
1.5 (summary project)											
Program 2) Nuclear Measurements and Effects											
2.1				X				X			
2.2a		X	X			X	X	X	X	X	X
2.2b						X	X	X	X	X	
2.3							X	X	X		
Program 3) Structures Material, and Equipment											
3.1								X		X	
3.1u								X		X	
3.3								X		X	
3.4								X		X	
3.5								X			
3.6										X	
3.7								X		X	
3.8								X		X	
3.9								X		X	
3.11								X		X	
3.12								X		X	
3.13								X		X	
3.14								X		X	
3.15								X		X	
3.16								X		X	
3.18										X	
3.19								X		X	
3.20								X		X	

3.21								X		X	
3.22								X		X	
3.24								X		X	
3.26								X		X	
3.27								X			
3.28.1								X		X	
3.28.2								X		X	
3.28.3								X		X	
3.29								X			
3.30							X	X	X	X	X
Program 4) Biomedical Effects											
4.1				X				X			
4.2								X	X	X	
4.5	X	X				X	X		X		X
4.7										X	
4.8										X	
Program 5) Aircraft Structures Test											
5.1	X	X				X	X	X	X		
5.2				X				X			
5.3								X			
Program 6) Test of Service Equipment and Operations											
6.2	X	X	X	X	X	X	X	X	X	X	X
6.3	X	X		X		X	X	X	X	X	X
6.4							X		X		
6.7	X	X	X	X	X	X	X	X	X	X	X
6.8	X	X		X		X	X	X	X		
6.8a	X	X	X		X	X	X	X	X		
6.9	X	X	X			X	X				
6.10	X	X				X	X	X	X	X	
6.11				X				X			
6.12	X	X	X	X	X	X	X	X	X	X	X
6.13							X	X	X	X	
Program 7) Long-Range Detection											
7.1	X	X	X	X	X	X	X	X	X	X	X
7.3	X	X	X	X	X	X	X	X	X	X	X
7.4	X	X	X	X	X	X	X	X	X	X	X
7.5	X	X	X	X	X	X	X	X	X	X	X
Program 8) Thermal Measurements and Effects											
8.1a			X		X	X	X	X		X	
8.1b	X		X				X	X	X	X	
8.2	X	X	X	X	X	X	X	X	X	X	
8.4.1										X	
8.4.2										X	
8.5		X						X		X	
8.6								X		X	

8.9								X		X	X
8.10			X	X				X		X	X
8.11a								X		X	
8.11b				X				X		X	
8.12a								X		X	
8.12b								X		X	
8.13								X			
Program 9) Technical Photography											
9.1	X	X	X	X	X	X	X	X	X	X	X
9.6								X		X	
9.7								X		X	

DoD NWE PROGRAMS AND PROJECTS ON TEAPOT: 2/18/55 – 5/15/55

The DoD projects that were conducted on the seven effects measurements programs, during Operation TEAPOT are listed below. The tests on which each project was conducted are cited in Table I-5. (Ponton 1981b, 81-114; United States Atomic Energy Commission 1969: 35-37; Jackson 1993: 13-1 – 13-16)

Program 1) Blast Pressure Measurements

1.1 Measurement of Free Air Atomic Blast Pressure – Air Force Cambridge Research Center. (WT-1101)
1.2 Shock Wave Photography – Naval Ordnance Laboratory. (WT-1102)
1.3 Microbarographic Pressure Measurements at Ground Level from High Altitude Shot – Sandia Laboratory. (WT-1103)
1.5 Preshock Sound Velocities Near The Ground in the Vicinity of an Atomic Explosion – Navy Electronics Laboratory. (WT-1104)
1.6 Crater Measurements – Engineer Research and Development Laboratories; Ballistic Research Laboratories. (WT-1105)
1.7 Underground Explosion Effects – Stanford Research Institute. (WT-1106)
1.9 Material Velocity Measurements of a High Altitude Shot – Sandia Laboratory. (WT-1108)
1.10 Overpressure and Dynamic Pressure versus Time and Distance – Stanford Research Institute. (WT-1109)
1.11 Special Measurements of Dynamic Pressure versus Time and Distance – Sandia Laboratory. (WT-1110)
1.12 Drag Force Measurements – Naval Ordnance Laboratory. (WT-1111)
1.13 Dust Density versus Time and Distance in the Shock Wave – US Army Chemical Corps. (WT-1113)
1.14a Transient Drag Characteristics on Spherical Models – Ballistic Research Laboratories. (WT-1114)
1.14b Measurements of Air-Blast Phenomena with Self-Recording Gauges – Ballistic Research Laboratories. (WT-1155)

Program 2) Nuclear Radiation Effects

2.1 Gamma Exposure versus Distance – Army Signal Corps Engineering Laboratories. (WT-1115)
2.2 Neutron Flux Measurements – Naval Research Laboratory. (WT-1116)
2.3a Neutron-Induced Radioactive Isotopes in Soils -- Naval Radiological Defense Laboratory. (WT-1117)
2.3b Gamma Radiation Fields Above Fallout Contaminated Ground -- Naval Radiological Defense Laboratory. (WT-1225)
2.4 Gamma Dose Rate versus Time and Distance – Evans Signal Laboratory; Army Signal Engineering Laboratories. (WT-1118)
2.5.1 Fallout Studies – Chemical and Radiological Laboratory. (WT-1119)
2.5.2 Distribution and Intensity of Fallout from the Underground Shot – Naval Radiological Defense Laboratory. (WT-1154)
2.6 Radiation Energy Absorbed by Human Phantoms in a Fission Fallout Field – Naval Medical Research Institute. (WT-1120)

2.7 Shielding Studies – Army Chemical Center; Chemical and Radiological Laboratory; Bureau of Yards and Docks. (WT-1121)
2.8a Contact Radiation Hazard Associated with Contaminated Aircraft – Air Force Special Weapons Center. (WT-1122)
2.8b Manned Penetration of Atomic Clouds – Air Force Special Weapons Center. (WT-1156)

Program 3) Effects on Equipment and Structures
3.1 Response of Drag-type Equipment Targets in the Precursor Zone – Ballistic Research Laboratory. (WT-1123)
3.2 Study of Drag Loading of Structures in the Precursor Zone – Wright Air Development Center. (WT-1124)
3.3.1 Flexible Measuring Devices and Inspection of Operation JANGLE Structures - Bureau of Yards and Docks. (WT-1125)
3.3.2 Behavior of Underground Structures Subjected to an Underground Explosion - Office, Chief Engineers. (WT-1126)
3.4 Air Blast Effects on Underground Structures – Office, Chief of Engineers; Ballistic Research Laboratories. (WT-1127)
3.6 Evaluation of Earth Cover as Protection to Underground Structures - Bureau of Yards and Docks. (WT-1128)
3.7 Effect of Positive Phase Length of Blast on Drag Type Structural Buildings – Air Force Special Weapons Center; Wright Air Development Center. (WT-1129)
3.8 Test of Concrete Panels – Bureau of Yards and Docks. (WT-1130)
3.9 Response of Small Petroleum Products Storage Tanks – Wright Air Command. (WT-1131)
3.10 Structures Information – Ballistic Research Laboratories. (WT-1107)

Program 5) Aircraft Structures
5.1 Destructive Loads on Aircraft in Flight: Bee, Apple 1, HA, MET, Apple 2 – Wright Air Development Center; Air Proving Ground. (WT-1132)
5.2 Effects on Fighter Type Aircraft in Flight – Wright Air Development Center. (WT-1133)
5.4 Evaluation of Fireball Lethality Using Basic Missile Structures – Wright Air Development Center. (WT-1134)
5.5a Effect of Nuclear Explosions on Fighter Aircraft – Wright Air Development Center; University of Dayton. (WT-1135)
5.5b Thermoelastic Response of Aluminum Box Beam – Wright Air Development Center; University of Dayton. (WT-1136)

Program 6) Electromagnetic Effects and Tests of Service Equipment
6.1.1a Evaluation of Military Radiac Equipment – Army Signal Corps Engineering Laboratories. (WT-1137)
6.1.1b Evaluation of Radiological Defense Warning System -- Army Signal Corps Engineering Laboratories. (WT-1112)
6.1.2 Accuracy of Military Radiacs – Naval Radiological Defense Laboratory. (WT-1138)
6.2 Effects on Selected Components and Systems - Army Signal Corps Engineering Laboratories. (WT-1139)
6.3 Missile Detonation Locator - Army Signal Corps Engineering Laboratories. (WT-1140)

6.4 Test of IBDA Equipment – Wright Air Development Center. (WT-1141)
6.5 Test of Airborne Naval Radars for IBDA – Bureau of Aeronautics. (WT-1142)

Program 8) Thermal Radiation Effects
8.1 Measurement of Direct and Ground-reflected Thermal Radiation at Altitude – Navy Bureau of Aeronautics. (WT-1143)
8.3 Protection Afforded by Operational Smoke Screens Against Thermal Radiation – Army Chemical Center, Chemical and Radiological Laboratories, 2d Chemical Weapons Battalion. (WT-1144)
8.4a Thermal Measurements from Aircraft in Flight – Naval Radiological Defense Laboratory. (WT-1145)
8.4b Thermal Measurements from Fixed Ground Installations – Naval Radiological Defense Laboratory. (WT-1146)
8.4c Thermal Measurements Prior to the First Maximum – Naval Radiological Defense Laboratory. (WT-1147)
8.4d Spectrometer Measurements – Naval Radiological Defense Laboratory. (WT-1148)
8.4e Air Temperature Measurements - Naval Radiological Defense Laboratory. (WT-1149)
8.4f Bolometer Measurements - Naval Radiological Defense Laboratory. (WT-1150)

Program 9) Supporting Measurements
9.1 Technical Photography – Air Force Special Weapons Center; Lookout Mountain EG&G; Army Map Service. (WT-1151)
9.4 Atomic Cloud Growth Study – Air Force Cambridge Research Center; EG&G; Army Map Service; Strategic Air Command; US Weather Bureau. (WT-1152)
9.6 Weather Reconnaissance – Air Weather Service.

Table I-5. DoD NWE Projects Conducted on TEAPOT Tests.
(Ponton et.al 1981b:83)

TEST → / PROJECT	WASP	MOTH	TESLA	TURK	HORNET	BEE	ESS	APPLE1	WASP'	HA	POST	MET	APPLE2	ZUCCHINI
Program 1) Blast Pressure Measurements														
1.1				X				X		X				
1.2	X		X	X		X	X	X	X	X	X	X		
1.3										X				
1.5								X				X		
1.6							X							
1.7							X							
1.9										X				
1.10						X						X		
1.11				X								X		
1.12												X		
1.13												X		
1.14a												X		
1.14b	X	X	X	X	X	X		X			X	X	X	X
Program 2) Nuclear Radiation Effects														
2.1	X	X	X	X	X	X	X	X	X	X	X	X		
2.2	X	X	X		X	X		X	X	X	X	X		
2.3a	X	X	X		X		X							
2.3b							X							
2.4	X	X	X				X		X					
2.5.1							X							
2.5.2							X							
2.6	X			X			X	X				X	X	
2.7	X		X	X	X		X	X			X	X	X	
2.8a	X	X	X	X	X	X		X	X	X	X	X	X	X
2.8b						X		X				X	X	X
Program 3) Effects on Equipment and Structures														
3.1	X	X	X	X	X	X		X	X		X	X	X	
3.2												X		
3.3.1							X							
3.3.2							X							
3.4												X		
3.6												X		
3.7												X		
3.8												X		

3.9												X		
3.10												X		
Program 5) Aircraft Structures														
5.1						X						X		
5.2				X	X	X		X				X	X	
5.4												X		
5.5a												X		
5.5b												X		
Program 6) Electromagnetic Effects and Tests of Service Equipment														
6.1.1a	X			X	X	X	X	X				X		
6.1.1b	X	X	X	X	X	X		X						
6.1.2							X	X				X		
6.2								X				X		
6.3	X	X	X	X	X	X	X	X	X	X	X	X	X	
6.4	X	X	X	X	X	X		X	X	X	X	X	X	X
6.5				X	X	X		X				X	X	X
Program 8) Thermal Radiation Effects														
8.1				X		X		X				X	X	
8.3					X									
8.4a										X				
8.4b	X	X	X		X	X			X	X		X		
8.4c	X								X	X				
8.4d	X	X	X		X	X		X	X	X	X			
8.4e				X								X		
8.4f	X	X		X	X	X			X	X	X			
Program 9) Supporting Measurements														
9.1	X	X	X	X	X	X	X	X	X	X	X	X	X	X
9.4	X	X	X	X	X	X	X	X	X	X	X	X	X	X
9.6	X	X	X	X	X	X	X	X	X	X	X	X		X

DoD NWE PROGRAMS AND PROJECTS ON PLUMBBOB: 5/15/57 - 10/7/57

The projects conducted on DoD's 8 effects measurements programs during PLUMBBOB, are listed below. The tests on which each of the projects were conducted are in Table I-6.(Harris 1981b:108-148; Jackson 1993:16-1 - 16-14)

Program 1) Blast and Shock

1.1 Basic Airblast Phenomena - Ballistic Research Laboratories. (WT-1401)
1.2 Field Test of a System for Measuring Blast Phenomena by Airborne Gauges - Naval Ordnance Laboratory; American Machine and Foundry Company; EG&G. (ITR-1402)
1.3 Air-Blast Phenomena in the High Pressure Region - Stanford Research Institute. (WT-1403)
1.4 Ground Acceleration, Stress, and Strain at High Incident Overpressures - Stanford Research Institute. (WT-1404)
1.5 Ground Motion Studies at High Incident Overpressure - Sandia Corporation. (WT-1405)
1.7Loading On Simulated Buried Structures at High Incident Overpressures - Air Research and Development Command. (WT-1406)
1.8a & 1.8 c Effects of Rough and Sloping Terrain on Airblast Phenomena -- Ballistics Research Laboratories, Stanford Research Center. (WT-1407 & ITR-1409)
1.8b Effects of Rough Terrain on Drag-Sensitive Targets - Ballistic Research Laboratories. (WT-1408)
1.9 Spectra of Ground Shocks Produced by Nuclear Detonations - Air Research and Development Command; Ramo-Woolridge Corporation. (WT-1487)

Program 2) Nuclear Radiation Effects

2.1 Soil Activation by Neutrons - Army Chemical Warfare Laboratory. (WT-1410)
2.2 Neutron-Induced Activity in Soil Elements - Naval Radiological Defense Laboratory. (WT-1411)
2.3 Neutron Flux From Selected Nuclear Devices -- Army Chemical Warfare Laboratories. (WT-1412)
2.4 Neutron and Initial-Gamma Shielding - U.S. Army Chemical Warfare Laboratories. (WT-1413)
2.5 Initial Gamma Radiation Intensity and Neutron-Induced Gamma Radiation of NTS Soil - Army Signal Research and Development Laboratories; Wright Air Development Center. (WT-1414)
2.6 Evaluation of New Types of Radiac Instruments - U. S. Army Signal and Research Laboratories. (WT-1415)
2.7 Investigation of Effects of Nuclear Detonations on Electromagnetic Wave Propagation and Nuclear Radiation Detector Design - Naval Research Laboratory. (WT-1416)
2.8 Evaluation of Military Radiac -- Naval Material Laboratory. (WT-1417)
2.9 Nuclear Radiation Received by Aircrews Firing the MB-1 Rocket -- Air Force Special Weapons Center. (WT-1418)
2.10 Initial Neutron and Gamma Air-Earth Interface Measurements -- Air Force Special Weapons Center. (WT-1419)
2.11 Neutron and Gamma Radiation from Shot Laplace - Naval Radiological Defense Laboratory; Army Chemical Warfare Laboratories. (WT-1541)

Program 3) Effects On Structures
3.1 Blast Loading and Response of Underground Concrete-Arch Protective Structures - U. S. Army Engineer Waterways Experiment Station; U. S. Naval Civil Engineering Laboratory. (WT-1420)
3.2 Evaluation of Buried Conduits as Personal Shelters - Bureau of Yards and Docks; U. S. Naval Civil Engineering Laboratory. (WT-1421)
3.3 Evaluation of Buried Corrugated-Steel Arch Structures and Associated Components - Bureau of Yards and Docks; U. S. Naval Civil Engineering Laboratory. (WT-1422)
3.4 Blast Effects on Existing UPSHOT-KNOTHOLE and TEAPOT Structures - Armour Research Foundation, Chicago Illinois; Air Force Special Weapons Center. (WT-1423)
3.5 Isolation of Structures from Ground Shock - Stanford Research Institute. (WT-1424 & WT-1424-1)
3.6 Full-Scale Field Tests of Dome and Arch Structures - Air Force Special Weapons Center. (WT-1425 & ITR-1448)
3.7 Instrumentation of Structures for Air-Blast and Ground-Shock Effects - Ballistic Research Laboratories. (WT-1426)
3.8 Soil Survey and Backfill Control in Frenchman Flat - U. S. Army Engineer Waterways Experiment Station. (WT-1427)

Program 4) Biomedical
4.1 Effects of Nuclear Detonations on a Large Biological Specimen (Swine) - Walter Reed Army Institute of Research. (WT-1428)
4.2 Evaluation of the Eye Protection Afforded by an Electromechanical Shutter: Diablo B Tactical Air Command; Air Force School of Aviation Medicine; Navy Radiological Defense Laboratory; Wright Patterson Aero Medical Laboratory; Nellis AFB Hospital. (WT-1429)
4.3 Secondary Missiles Generated by Nuclear-Produced Blast Waves -- Lovelace Foundation for Medical Education and Research. (DNA 6005f, Harris P. S. et.al :1981b)

Program 5) Aircraft Structures
5.1 In-Flight Structural Response to the HHS-1 Helicopter to a Nuclear Detonation -- Navy Bureau of Aeronautics. (WT-1430)
5.2 Structural Response and Gas Dynamics of an Airship Exposed to a Nuclear Detonation -- Navy Bureau of Aeronautics; Aeronautical Structures Laboratory; Naval Air Material Center. (WT-1431)
5.3 In-Flight Structural Response of a FJ-4 Aircraft to a Nuclear Detonation -- Naval Air Special Weapons Facility. (WT-1432)
5.4 In-Flight Structural Response of an A4D-1 Aircraft to a Nuclear Detonation -- Navy Bureau of Aeronautics; Naval Air Special Weapons Facility; North American Aviation. (WT-1433)
5.5 In-Flight Structural Response of a F-89D Aircraft to a Nuclear Detonation -- Wright Air Development Center; Northrop Aircraft. (WT-1434)

Program 6) Electromagnetic Effects and Tests of Service Equipment
6.1 Mine-Field Clearance by Nuclear Weapons - U. S. Army Engineer Research and Development Laboratories. (WT-1435)

6.2a Measurement of the Magnetic Component of the Electromagnetic Field Near a Nuclear Detonation -- Diamond Ordnance Fuze Laboratory. (WT-1436)
6.2bEffect of Nuclear Radiation on Semiconductor Devices – Diamond Ordnance Fuze Laboratory.(WT-1489)
6.3 Attenuation of Electromagnetic Radiation Through an Ionized Medium - U. S. Naval Air Development Center. (WT-1437)
6.4 Accuracy and Reliability of the Short-Baseline NAROL System -- Air Force Cambridge Research Center. (WT-1438)
6.5 Effects of Nuclear Detonations on Nike Hercules -- White Sands Missile Range; Bell Telephone Laboratories. (WT-1439)

Program 8) Thermal Radiation Effects
8.1 Thermal Protection of the Individual Soldier - U. S. Army Quartermaster Research and Engineering Command. (WT-1440)
8.2 Prediction of Thermal Protection of Uniforms, and Thermal Effects on a Standard-Reference Material - Naval Material Laboratory. (WT-1441)
8.3a Performance of a High-Speed Spectrographic System -- U. S. Naval Radiological Defense Laboratory. (WT-1442)
8.3b Instrumentation for Measuring Effects Phenomena Inside the Fireball - Wright Air Development Center. (WT-1443)

Program 9) Supporting Measurements
9.1 Support Photography - AFSWP; Military Air Transport Service; EG&G.

Table I-6. DoD NWE PROJECTS CONDUCTED ON PLUMBBOB Tests.
(Magg, Ponton et.al 1981: 62,76-77; Harris et.al. 1981b: 109-10)

TEST → / PROJECT	BOLTZMANN	FRANKLIN	LASSEN	WILSON	PRISCILLA	HOOD	DIABLO	JOHN	KEPLER	OWENS	STOKES	SHASTA	DOPPLER	FRANKLIN'	SMOKY	GALILEO	WHEELER	LAPLACE	FIZEAU	NEWTON	RAINIER	WHITNEY	CHARLESTON	MORGAN
Program 1) Blast Measurements																								
1.1		X		X	X	X		X	X	X	X	X				X							X	X
1.2									X	X														
1.3					X																			
1.4					X																			
1.5					X																			
1.6					X																			
1.7					X																			
1.8															X									
1.9											X				X	X						X	X	
Program 2) Nuclear Radiation Studies																								
2.0*																		X						
2.1		X	X	X	X					X														
2.2				X		X				X								X						
2.3		X	X	X	X	X		X		X					X			X						
2.4		X	X	X	X	X				X														
2.5	X	X	X	X		X		X		X														
2.6		X	X	X	X	X																		
2.7	X		X	X	X	X	X		X	X														
2.8				X	X	X	X																	
2.9								X																
2.10	X		X	X		X	X	X	X	X														
Program 3) Effects on Structures																								
3.1					X																			
3.2					X																			
3.3					X																			
3.4					X																			
3.5					X																			
3.6					X																			
3.7					X																			

3.8					X																			
Program 4) Biomedical Effects																								
4.1		X		X	X																			
4.2	X			X	X	X	X																	
4.3					X										X	X								
Program 5) Effects on Aircraft Structures																								
5.1	X	X		X	X		X		X	X	X													
5.2		X									X													
5.3	X					X	X		X			X	X		X									
5.4	X				X	X	X					X	X		X									
5.5	X	X		X	X	X	X	X	X	X	X	X	X	X	X									
Program 6) Electromagnetic Effects																								
6.1					X																			
6.2a & b			X	X	X	X	X			X														
6.3		X	X	X	X																			
6.4	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X		X	
6.5	X	X	X	X		X			X	X									X					X
Program 8) Thermal Radiation and Effects																								
8.1					X																			
8.2			X	X	X	X																		
8.3a			X	X	X		X																	
8.3b					X										X									
Program 9) Support Photography																								
9.1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

* No other project has a ".0" number. This project is sometimes referred to as 2.11 rather than 2.0.

DoD NWE PROGRAMS AND PROJECTS ON HARDTACK II: 9/12/58 – 10/30/58

The five programs and their projects conducted for effects measurements during Operation HARDTACK II are listed below. The tests on which each project was conducted are cited in Table I-7.(Ponton 1982d: 88-181; Jackson 1993: 19-1 to 19-5)

Program 1) Blast and Shock

1.7 Airblast Phenomena and Instrumentation of Structures – Ballistic Research Laboratories. (WT-1612)

Program 2) Nuclear Radiation and Effects

2.12a Neutron Flux from Very-Low-Yield Bursts – Chemical Warfare Laboratories. (WT-1679)

2.12b Gamma Dose from Very-Low-Yield Bursts – Chemical Warfare Laboratories and the Chemical Corps Training Command. (WT-1677)

2.12c Soil Activation by Neutrons from Very-Low-Yield Bursts: Hamilton – Chemical Warfare Laboratories and Army Chemical Center. (WT-1680)

2.12d Thermal Radiation from Very-Low-Yield Bursts – Chemical Warfare Laboratories. (WT-1676)

2.13 Gamma Radiation and Induced Activity from Very-Low-Yield Bursts – AFSWC. (WT-1681)

Program 4) Biomedical Effects

4.2 Effects of Very-Low-Yield Bursts on Biological Specimens (Mice and Swine) – Walter Reed Army Institute of Research. (WT-1663)

4.3 Effects of Light from Very-Low-Yield Nuclear Detonations on Vision (Dazzle) of Combat Personnel: Hamilton – Headquarters, Continental Army Command. (WT-1664)

Program 6) Tests of Service Equipment and Materials

6.14 Proof Test of Flash-ranging Equipment – Army Artillery Board and the Signal Research and Development Laboratories. (WT-1661)

6.15 Electromagnetic Pulses from Low-Yield Bursts – Signal Research and Development Laboratories. (WT-1662)

Program 8) Thermal Radiation and Effects

8.8 Thermal Radiation from Low-Yield Nuclear Bursts – Air Force Cambridge Research Center. (WT-1675)

Table I-7.DoD NWE PROJECTS CONDUCTED ON HARDTACK II TESTS. (Ponton et. al. 1982d:88-181)

TEST → / PROJECT	EDDY	MORA	TAMALPAIS	QUAY	LEA	HAMILTON	LOGAN	DONA ANA	RIO ARRIBA	SOCORRO	WRANGELL	RUSHMORE	STANFORD	DE BACA	EVANS	MAZAMA	HUMBOLT	SANTA FE	BLANCA
Program 1) Blast and Shock																			
1.7	X	X		X	X	X				X		X			X		X		
Program 2) Nuclear Radiation and Effects																			
2.12a						X											X		
2.12b						X											X		
2.12c						X													
2.12d						X													
2.13						X													
Program 4) Biomedical Effects																			
4.2						X											X		
4.3						X													
Program 6) Tests of Service Equipment and Materials																			
6.14		X		X	X	X		X	X	X	X								
6.15		X	X	X	X	X	X	X	X	X	X								
Program 8) Thermal Radiation and Effects																			
8.8				X		X			X	X	X	X	X	X		X	X	X	

The only DoD project conducted on the safety tests was 6.15 on : Mars, Hidalgo, Neptune, and Vesta.

CHAPTER I-2. DoD NWE PROJECTS BY TECHNICAL AREA

TECHNICAL AREAS for DoD NWE PROJECTS

The technical areas used here are intended to enable the reader to easily locate projects in a technical area of interest. Although the DoD was fairly consistent with program numbers representing technical areas, this was not always the case. The Civil Defense programs are even more diverse. Within each technical area, the projects are organized by operation, in chronological order, then by increasing project number within that operation. It is intended that this organization will enable a reader to zero in on the projects of particular technical interest and to easily follow projects of a similar technical nature through the operations. During this pioneering era of nuclear effects, the changes with time during the 1950s were significant.

The organization used herein for describing projects is by technical areas, which are identified alphabetically, in the following.

* Synopses of the activities performed in the projects within this technical area are given in the next section "Synopses of Field Activities Conducted in Some Technical Areas".

CORRELATION OF "PROGRAM#.PROJECT#" AND TECHNICAL AREA

Table I-9 indicates where each project (identified by Program#.Project#) is discussed in the next section. For those projects that are essentially the same as a previously conducted project, the operation and Program#.Project# number of that earlier project is given (for instance, see below JANGLE 2.4b was the same as BUSTER 4.1).

Table 1-9. CORRELATION OF "PROGRAM#.PROJECT#" AND TECHNICAL AREA

BUSTER					
Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area
2.2	Ad	2.3	Ag	2.4a	Af
2.4b	Af	2.4-1	Ha	2.4-2	Ag
2.6	Ab	3.5	Ae	3.8	Aa
3.9	Ac	4.1	Bd	4.2	Ba
4.2a	Ba	4.3	Bb	6.1b	Ia
6.4	Ia	6.5	Ib	6.9	Ja
7.1	Ma	7.2	Me	7.3	Ma
7.5	Mb	7.6	Mc	8.2	Ka
8.4	Kb	9.1a	G	9.1b	G
JANGLE					
Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area
1.1	E	1.2a-1	Ca	1.2a-2	E
1.2b	E	1.3a	Ca	1.3b	Cb
1.3c	Cd	1.4	Cc	1.5a	E
1.5b	E	1.6	F	1.7	F
1(8)-b	BUSTER 8.2	1(9)-a	E	1(9)-b	Cb
2.1a	Hb	2.1b	Hb	2.1c-1	Ia
2.1c-2	Ia	2.1d	L	2.3-1	Hb
2.3-2	Ab	2.4a	L	2.4b	BUSTER 4.1
2.4c	L	2.5a-1	L	2.5a-2	L
2.5a-3	L	2.6a	L	2.6c-1	L
2.6c-2	L	2.6c-3	L	2.7	Ba
2.8	L	3.1	G	3.2	G
3.3	G	3.28	E	3.29	E
4.1	Kb	4.1a-1	Kb	4.1a-2	Kb
4.2	E	4.5	Ah	6.1	Ia
6.2	Jb	6.3-1	Af	6.3-2	Bc
6.4	BUSTER 6.5	6.7	Jb	6.8	Ac
7.1a	BUSTER 7.1	7.1b	BUSTER 7.3	7.2	BUSTER 7.5
7.3	BUSTER 7.6	8.4	BUSTER 8.4		

TUMBLER-SNAPPER					
Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area
1.1	Cd	1.2	Cc	1.3	Cc
1.4	Ca	1.5	Cb	1.6	E
1.7	E	1.9	Ce	1.13	Cc
2.1	Hb	2.2	Ia	2.3	Hb
3.1	G	3.3	Ad	3.4	Ae
4.2	Ba	4.3	Ba	4.4	Me
4.5	Bb	4.6	Ba	6.1	Ia
6.3	Aa	6.4	Ib	6.5	Jb
6.7	Ia	7.1a	Md	7.1b	BUSTER 7.2
7.2	Mc	7.3	BUSTER 7.1&7.3	7.4	Mb
8.1	Ad	8.2	Ha	8.3	Ha
8.3a	Ha	8.4	Ka	8.5	Ag
8.6	Cc	8.7	Ha	9.1	Kb
9.2	BUSTER 8.2	9.4	Ja	9.5	Ja
UPSHOT-KNOTHOLE					
Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area
1.1a/1.2	Cc	1.1a-1	D	1.1a-2	D
1.1b	Cc	1.1c-1	Cc	1.1c-2	Cc &Cf
1.1d	Cc	1.3	Cd	1.4a	E
1.4b	E	1.5	Cc	2.1	Aa
2.2a	L	2.2b	Bd	2.3	Hb
3.1	G	3.1u	G	3.3	G
3.4	G	3.5	G	3.6	G
3.7	G	3.8	G	3.9	G
3.11-3.16	G	3.18	Ae	3.19	Ad
3.20	Ak	3.21	Ai	3.22	G
3.24	Ai	3.26	Ak	3.27	Ak
3.28.1	Cc	3.28.2	Cc	3.28.3	Cc
3.29	G	3.30	Cc	4.1	Ba
4.2	Ba	4.5	Bb	4.7	L
4.8	Ba	5.1	Aa	5.2	Aa
5.3	Aa	6.2	Ib	6.3	Ib
6.4	Ia	6.7	Md	6.8	Ia
6.8a	Ia	6.9	Ia	6.10	Ia
6.11	Ib	6.12	Ib	6.13	Ib
7.1	Md	7.3	Mc	7.4	Mb
7.5	Ma	8.1a	Aa	8.1b	Aa

8.2	Ha	8.4-1	Cg	8.4-2	Cg
8.5	Ba	8.6	Af	8.9	Bd
8.10	Ha	8.11a	Ak	8.11b	Ak
8.12a	Cc	8.12b	Cc	8.13	Ag
9.1	Kb	9.6	Kb	9.7	Kb

TEAPOT					
Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area
1.1	Cd	1.2	Cb	1.3	Cc
1.5	Cc	1.6	E	1.7	E
1.9	Cd	1.10	Cc	1.11	Cc
1.12	Cc	1.13	Cc	1.14a	Cc
1.14b	Cc	2.1	Hb	2.2	Hb
2.3a	L	2.3b	L	2.4	L
2.5.1	L	2.5.2	L	2.6	Bd
2.7	Hb	2.8a	Jb	2.8b	Aa
3.1	Ai	3.2	G	3.3.1	G
3.3.2	G	3.4	G	3.6	G
3.7	G	3.8	G	3.9	Ak
3.10	E	5.1	Aa	5.2	Aa
5.4	Aj	5.5a	Aa	5.5b	Aa
6.1.1a	Ia	6.1.1b	Ia	6.1.2	Ia
6.2	Ak	6.3	Md	6.4	Ib
6.5	Ib	8.1	Aa	8.3	Ha
8.4a	Aa	8.4b	Ha	8.4c	Ha
8.4d	Ha	8.4e	Ha	8.4f	Ha
9.1	U-K 9.1	9.4	Kb	9.6	Ka
PLUMBBOB					
Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area
1.1	Cc	1.2	Cc	1.3	Cc
1.4	E	1.5	E	1.7	E
1.8a	Cf	1.8b	Ai	1.8c	Cf
1.9	F	2.1	L	2.2	L
2.3	Hb	2.4	Ai	2.5	Hb
2.6	Ia	2.7	Ja	2.8	Bd
2.9	Bc	2.10	Hb	2.11	L
3.1	G	3.2	G	3.3	G
3.4	G	3.5	G	3.6	G
3.7	E	3.8	E	4.1	Ba
4.2	Bb	4.3	Ah	5.1	Aa
5.2	Aa	5.3	Aa	5.4	Aa
5.5	Aa	6.1	Ae	6.2	Ae
6.2a	Ak	6.3	Ja	6.4	Ib
6.5	Aa	8.1	Ba	8.2	Af
8.3a	Ha	8.3b	Aj	9.1	Kb

HARDTACK II					
Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area
1.7	Cc	2.12a	Hb	2.12b	Hb
2.12c	Hb	2.12d	Ha	2.13	Hb
4.2	Ba	4.3	Bb	6.14	Ib
6.15	Od	8.8	Ha		

SYNOPESES OF FIELD ACTIVITIES CONDUCTED IN SOME TECHNICAL AREAS

This section is presented before beginning discussion of the specific projects. Many of the projects conducted in a technical area have a great number of similarities in terms of the activities that were conducted in the field. This section attempts to summarize the main activities undertaken for the projects in a few of the technical areas. It is hoped that these summaries will provide a general understanding of the field activities undertaken in these areas so that they need not be repeated for each of the projects described in the following.

It is emphasized that the field activities described herein were only a small part of the total activities of a project. Many or most project activities would occur in offices, meeting rooms, and laboratories "back home" before and after the project came to the field. Although the field activities might have been small compared to the total activities, they were essential, for acquiring information used to validate concepts and theories regarding nuclear environments.

Exposure Projects

The most numerous of the effects projects conducted during atmospheric testing are termed herein *exposure projects*. These projects consisted of exposing objects to different levels of a nuclear environment and analyzing how the exposures affected the object. Animal, vegetable, and mineral objects were used in the DoD exposure projects; but military equipment was the largest category. It can be argued that ALL projects at NTS, not just those identified as such herein were really exposure projects.

The characteristics of the nuclear environment(s) to which an object was to be exposed was estimated before the shot. Such estimates were the basis of much of AFSWP's work. It should be kept in mind that at the time of BUSTER, such estimates had more uncertainty than would be the case for later operations.

Objects to be exposed would arrive at the NTS at varying times, months to hours before detonation, depending on the objects. Some of the objects might be assembled or partially assembled at the site, others might be sent directly from the home base or laboratory, ready to expose.

Objects would usually be placed for exposure at more than one distance from the detonation. Often three distances were used which represented: over exposure; expected or desired exposure; and under exposure. If objects were placed at only one distance and the actual yield differed appreciably from the anticipated yield, or if the estimates were poor, the objectives of the project probably would not be met. Using at least three exposures was "hedging your bet" and provided the possibility of getting data over a range of environments.

Post-shot, the exposed objects were either examined where they had been placed in the field and/or or retrieved from the field for examination in the laboratory. In some cases, for example when radioactivity was the effect of interest, early time retrieval of the objects was essential, before decay caused the measurements to be less accurate or impossible. Simple procedures were devised for early time retrieval, such as attaching the objects to cables (or placing the objects on sleds attached to cables) so that they could be pulled away from the

hazardous exposure area to an area with a lower level of radiation acceptable for humans. More sophisticated means were also used, such as an army recovery tank with access to objects through its floor.

For technical reasons like data interpretation, objects exposed to radiations often needed to be protected from the subsequent airblast and/or ground motion. A wide variety of innovative devices were developed and used to isolate objects exposed to radiation.

In other cases, the assessment of damage due to airblast was not an issue; and postshot examinations could occur when hazardous radiation conditions had subsided in the field.

In yet other cases (like structures, vehicles, aircraft exposures), exposure and the resulting damage due to airblast and ground motion was the objective of the measurements.

Photography was extensively used in the field and the laboratory to document pre- and post-test conditions. For comparison purposes, a set of "control samples", just like those exposed, might have remained at the laboratory.

Biomedical Exposures, Animals

The use of animals was the most frequent type of biomedical exposure. These projects, with their wide range of objectives, were generally aimed at obtaining information that could be applied to humans. Mice were perhaps used in the greatest numbers. Chester swine were often used in large numbers because their skin is fairly similar to that of humans. Dogs, goats, and sheep were commonly used, and monkeys were used on occasion. In one PLUMBBOB FCDA project, obstinate burros were used to examine effects on large animals.

Animals were brought to the site and cared for by attendants. Often, these attendant jobs were not easy, especially when the unexpected happened – like when the pigs outgrew their uniforms due to schedule delays. Care was considered "highly specialized" at the *Pork Sheraton*. Usually at a few hours prior to the shot, the animals were taken to their containers and/or harnesses. In some cases, the animals were anesthetized prior to the shot.

The animals were usually placed inside of a harness or container of some sort of ingenious design. The containers might be open (constructed of a wire mesh) or closed cages with or without exposure holes. They might be placed in the open field or inside a structure. The containers themselves might be designed to eliminate certain kinds of radiation or other nuclear effect, like air blast or ground shock, but allowing the effect of interest to pass through to the animal. (For instance, if the effect of neutrons was of interest, the gammas might need to be separated out; and the container would include materials that absorb gammas.) Sometimes the containers and/or buildings would be instrumented with radiation gages, pressure gauges, photographic systems, etc.

Harnesses, again often of ingenious design, also might be used to hold an animal in a particular position during exposure. For instance, it might be important that one side or part of the animal be exposed at the time of detonation. The animals might be "dressed". For

instance pigs were sometimes dressed in uniforms made of military textiles, some animals were dressed in outfits that might also serve as a harness.

Postshot, the animals were retrieved and probably photographed, perhaps even given a brief examination. They would then be taken back to Mercury where they might undergo a more detailed examination(s) and/or be transported back to a laboratory. Some projects involved killing the animals, perhaps at specified time intervals, to examine certain inner organs such as lungs, liver, heart as a function of time after exposure. Some projects conducted observations of the exposed animals over a long term, perhaps years, in order to study changes. For the purpose of comparison, a *control group* of animals of the same background as the exposed animals might be maintained in either laboratory or natural environments, but they were not exposed.

Airblast, Ground Motion, and Thermal Measurements

AFSWP sought the capability to be able to predict the environmental conditions resulting from nuclear explosion of different yields and detonation locations. The environmental conditions of pressure, velocity and displacements, and temperature resulting from radiations, airblast and/or ground motion at different distances from the detonation were all of interest. They sought to determine the magnitude of each of the NWEs as a function of distance from GZ and as a function of the yield and height (or depth) of the detonation. To do this, numerous measurements were conducted for each of the NWEs.

The resulting data was analyzed and organized in handbooks for rapid use by field commanders and/or researchers. These handbooks were refined over the years as new data became available and as theoretical models and numerical simulations became their working tools. The combination of predictions refined by measurements was just like that of weapons development. The resulting and ever improving capabilities for being able to predict nuclear environments represented a key product of AFSWP and its decedents.

Starting with JANGLE Sugar and Uncle, the shots on which the DoD conducted a significant number of NWE measurements used *blast lines**. These were straight radial lines from GZ along which instrumentation would be placed for the measurement of NWEs. There might be more than one blast line on a shot; and if so, they would often be run at about 90° or 180° directions from each other. [*Footnote: The blast line along which airblast and/or ground motion measurements were made was usually referred to as the *main blast line*. Although referred to as blast lines, measurements other than airblast and ground motion (e.g., thermal and nuclear radiations) might also be made along them.]

Because only so many folks and so much "stuff" can be in one place at one time, some of the fielding issues for blast lines were: the size of the equipment required for the measurements themselves as well as for their installation (for instance drill rigs, grouting equipment, etc.); how many people were involved when at a station; proximity to other projects or installations; time schedules for what or who was where when, etc. Such issues would be factors in determining whether one or more parallel lines or lines elsewhere would be used.

A number (generally three or more, often six-ten, sometimes more) of measurements for a NWE, which used the same or similar instrumentation, would be made by one organization. These measurements would be at different ranges from GZ along a blast line. Other organizations, probably using different instrumentation, might make measurements of the same or other NWEs along the same or a different blast line.

Line projects were usually fairly extensive. It was not uncommon for scores of measurements of a given NWE to be made by one organization along a blast line for one shot. These projects were usually conducted by one of a few organizations that were the technical leaders in such measurements. More than one organization might conduct the same or similar measurements on a given test. The advantages of what might appear to be duplication are described in the text.

Blast line projects would be responsible for providing their data, in usable form, to the other projects on a test. This saved the time, money, and effort that each project would expend if they had to obtain their own measurements. However, in some instances (such as if an exposure took place inside of a building), a project would require its own measurements away from the blast line.
Such measurements would usually be conducted as a separate project(s) by an organization with such expertise.

Locations for measurements would be above ground or underground along the blast line. Above ground locations were usually facilitated by using poles, but "goal posts" and towers were also used. Underground locations might be dug or drilled if significant depth was required; and some protective canister would probably be used to protect the instrument when the hole was backfilled. Generally, the group doing the measurement project had also developed the instrument and its canister.

After detonation, information regarding how the instrument interacted with the nuclear effect it measured, needed to be "recorded". Instruments generally produce information as an electrical signal. Recording of this signal might be done within the canister itself in the case of self recording instrumentation. Or, the information signal might be sent somewhere else for recording. Information signals might be sent by radio waves or over cable, traveling at the speed of light. At early times after detonation, cables were generally but not always more reliable than radio waves. Laying the miles of cable, usually buried in trenches, was a dirty and tedious job, even in the mildest of weather. Cable would connect the instrument to a recording station which often was a trailer that was parked farther from GZ than the measurements and usually in a revetment for added protection. For close-in DoD measurements, and for some of the weapons development experiments, elaborate underground recording stations near the instrument(s) might be required.

The amount of information being sent; the distance from the instrument to the recording station; the recording equipment itself; the equipment required to make the recorded signal intelligible to a viewer; and the methods of signal storage, retrieval, and analysis were all important factors of the project. Thus, a measurement consisted of a system of components and their inter-workings.

It is difficult to separate measurements from instrumentation development. It is probably fair to say that each time a measurement was made, the scientists gleaned ways of improving their measurement system and did so. Each of the components of the measurement systems used during atmospheric testing were undergoing tremendous technical advancement during the 1950s, and changes in the measurement systems were continuously made that took advantage of them.

If a project specifically states instrumentation development or evaluation in its main objectives, it is considered here as being an *Instrumentation Development* Project. (Only 2 NWE projects were so designated here, and they were both on UPSHOT-KNOTHOLE.) Otherwise, it is considered as a *Measurement* project. Instrumentation and system (transmission, recording, etc.) development was generally just done without it being a specified part of the project objectives. Experimenters often referred to their development work as having been "bootlegged".

Nuclear Radiations

Measurements of thermal and nuclear radiations often shared many similarities with the measurements of airblast and ground shock like the positioning of measurement stations along a line and instrumentation development and evaluation. Thermal radiation measurements were often made in close cooperation with the airblast and ground shock programs, and they represented important contributions to solving the non-ideal airblast issues. A key feature of many of the measurements involving nuclear radiations, neutrons and gammas in particular, was the time of recovery of the exposed samples and/or the devices used to make the measurement.

A number of innovative methods were used for rapid recovery of samples and/or measuring devices. Recovery by personnel was perhaps the most common. People would enter the field on vehicles as soon as radiation levels had subsided and stay no longer than prescribed, simply picking up by hand the devices and/or samples. Helicopters would sometimes be used. Trailers containing equipment for analyzing the samples/devices might be moved to the forward area(s), saving travel time. Means of easily removing samples/devices from their exposure positions were devised. If the objects were exposed on a cable, the cable might simply be pulled 1,000 yards or more out of the contaminated area. One project had samples automatically eject from their underground exposure position; and they were then towed on cable to a less contaminated area where radiation levels were acceptable for humans. Objects might be exposed on sleds which were attached to cables that were pulled out of the active areas. Some recoveries used a tank with a lot of shielding and an open able floor area. The success of a nuclear radiation project could depend on its rapid and effective recovery, and many innovative methods were used.

Structures

The structure to be tested might be a complete building, bridge, or shelter, perhaps even containing ventilation and other systems. Or, it might be an element of a structure that was

commonly used such as columns, walls, footings, or beams. In some cases, scaled models were designed for testing. Also, relatively inexpensive idealized shapes such as cylinders or rectangular parallelepipeds were constructed and tested in groups as a parametric study. A key part of the design process was the determination of the loads a structure would be able to withstand.

For a specific nuclear test, the locations where the design loads would be experienced was estimated, probably with AFSWP aiding the personnel conducting the project. A plan would then be developed to place the structure at one or more locations in the field. Again, it was often decided to use three locations and to construct three structures, representing loads that were: over design, at design, and under design. For large and expensive structures, only one location generally would be used which was usually near to or somewhat over design loading.

Construction of the structure would be conducted by an AEC contractor(s); but there would usually be continuous communication with the design group. During BUSTER-JANGLE, Reynolds Electric and Engineering Co. or Silas-Mason would probably have been the construction contractor. If possible, the structure might be constructed the same distance from GZ as a measurement instrument on the blast line and/or near the blast line. Instruments such as pressure-time gages or displacement-time might be installed for measuring structure-specific loads.

Post-shot more photographic coverage would take place as well as "hands-on" inspection. Some samples of the structure or its debris might be collected for special analyses back at the laboratory. Comparison of the structure's behavior in the field would be compared to that expected from the design.

<u>Service Operations Projects</u>

Service Operations Projects tested the important services that would be conducted on a nuclear battlefield: communications and decontamination are the 2 types described herein. The projects placed emphasis on conducting these services in the same manner as they were expected to take place on an actual nuclear battlefield.

<u>Support Projects</u>

Two types of Support Projects: Air Weather Service and Photography are considered. Although these were AFSWP projects, Support Projects provided support to the Test Director and Test Manager and to the other AFSWP projects. The Air Weather Service would continue throughout testing; but after TUMBLER-SNAPPER, this support would be handled directly through the AEC rather than as an AFSWP project. Photography projects would remain exceedingly important throughout NTS's history.

CHAPTER I-3. DoD NWE PROJECTS IN TECHNICAL AREAS

A: EXPOSURE PROJECTS

Aa. Aircraft Structures

BUSTER

3.8 Two aircraft, an F-47 fighter and a B-17 bomber, were both located on the ground 4,250 feet from the Dog GZ for this Wright Air Development Center (WADC) project. The fighter had its tail toward GZ, and the bomber had its left side facing GZ. These two aircraft were relocated for Easy where the fighter again had its tail toward the blast at a range of 2,675 feet, while the bomber had its nose toward GZ at 5,847 feet. Aircraft were also exposed on subsequent operations, often with instrumentation to measure the levels of airblast, ground motion, thermal and nuclear radiations.(Gilroy 1952: xiii)

TUMBLER-SNAPPER

3.1 Although aircraft were exposed on this project, they were exposed in positions with respect to structures which had been built that represented Russian revetments. See Section G. Structuures.

6.3 The Army Chemical Center (ACC) evaluated the filter units installed in the pressurization system of a B-29 aircraft that was flown through the radiation clouds of Easy, Fox, and George at about 30,000'. Radioactivity measurements of filtered and unfiltered air showed that the units worked well.(Ort 1952: 3, 30, AppendixA)

UPSHOT-KNOTHOLE

2.1 Two unmanned F-80 drone aircraft were flown through the atomic cloud on both Dixie and Harry in order to determine the inhalation hazard that would be encountered by the crew in pressurized aircraft encountering such a cloud on a bombing mission. A sampling system was designed by Chemical and Radiological Laboratories (CRL) to collect samples in the cockpit at different times of flight, and the samples were analyzed for activities and particle sizes. This project was coordinated with Project 4.1 of UPSHOT-KNOTHOLE which measured the radiation exposures in the cloud external to the drones. Also, results from JANGLE 2.7, which examined the inhalation hazards encountered by exposed dogs and sheep, were used in evaluating the hazard.(Capasso 1956: 3, 9-13)

5.1 Two standard blue Naval model AD aircraft were converted by the Navy Bureau of Aeronautics (NBA) to drone aircraft. They were instrumented for the measurement of NWE and aircraft response on: Annie, Nancy, Simon, Encore, and Harry. One of these craft was flown manned on Annie and the other on Harry. The instrumentation was extensive and included measurements for: burst time; thermal radiation; maximum aircraft skin temperatures; overpressure; acceleration of aircraft; wing bending, shear, and torsion; horizontal stabilizer bending and shear; aircraft altitude, velocity, and pitch; and gamma radiation. Many of these instruments were installed at more than one location on the craft (port, starboard, inside, etc.). For instance there were 19 plates for temperature and 7 gamma boxes. The drone flights were under control of: a ground pilot at take off; the pilot of the "mother" control plane in flight; and a pilot at the radar plotting board at the Control Point

(CP) during detonation. After detonation, the mother control plane regained control. Manned aircraft were also used to accompany the drone at some distance and to make observations.

On Simon, whose actual yield was greater than planned, there was an "unplanned" occurrence. At t=0, the drone AD aircraft were "to be in level flight attitude, tail toward the blast" -- "simulating an escape position of the craft following delivery of an atomic weapon".(Rogin 1954: 21) One drone was positioned for near maximum weapon effects, and "the higher thermal radiation severely weakened all the blue painted skin on the underside of the wing". Both the port and starboard outboard wing panels were torn off at the time of shock arrival as a result of the weakened skin and combined overpressure and gust effects." The panels were recovered after the test and had not incurred any significant additional damage due to the free fall and subsequent ground impact. "A considerable amount of valuable information on thermal damage to aircraft in flight was obtained from these panels--."(Rogin 1954: 3) (Author's comment – I think blue went out of style.)

5.2 Three B-50D aircraft were extensively instrumented for basic NWE measurements and aircraft response by WADC. They were manned and flown behind the manned drop aircraft on Dixie and Encore. On Dixie, load information was obtained in preparation for Encore. "The flight pattern for Encore was designed so that the 3 test aircraft would receive 100 percent of design limit loads".(Lenz 1953: 39-40) The 3 B-50Ds flew 200' behind and 200' below the drop airplane, effectively duplicating "the position which would exist for a drop airplane throughout bomb release, burst time, and shock arrival."(ibid. 41) Immediately after dropping the bomb, the drop plane made a sharp turn, accomplishing the 'breakaway' escape maneuver. The three test aircraft continued on a level flight path in vee formation. (ibid.41)

5.3 One B-36D had additional instrumentation installed by WADC and was flown on Encore in "an orbit identical to that flown by the drop aircraft except -- displaced upward 3000' and forward 4880'".(Purkey 1955:3, 15, 47)

8.1a WADC conducted a major effort exposing basic aircraft structures and components on Encore and Grable. Test specimens included: 8 box beams, 8 tension ties, 13 horizontal stabilizer and elevator assemblies, and 6 aircraft panels. Measurements of temperature and strain versus time were obtained at 4 ranges on Encore and at 5 on Grable.

Also exposed were: 31 aircraft panels, 99 craft undercarriage components, tire specimens, glass and plexiglas, hydraulic equipment, a B-36 wing outer panel and a B-36 stabilizer and elevator, and 212 panels of fabric and foil surface coverings. These exposures were conducted on Ruth, Ray, Badger and Simon at 3 or 4 ranges on each shot.(Schlie 1954: 3-6, 48)

8.1b Non-operational and previously exposed aircraft, a B-29 exposed in 4 previous shots and a B-17and B-45 each with one previous exposure, were again exposed in Yucca Flat. WADC had preshot and postshot still photography taken of all aircraft, and post shot examinations were conducted. Peak skin temperature was measured. Five fighter aircraft,

all of which had been damaged to various degrees in the TUMBLER tests, were also exposed in Frenchman Flat on Harry and Climax. (Freeh 1954: 3, 15-8)

CRAFT	SHOT	POSITION AND RANGE (ft)	CRAFT	SHOT	POSITION AND RANGE	SHOT	POSITION AND RANGE
B-29	Annie	Tail-in 7700	F-47	Harry	Nose-in 1725	Climax	Nose-in 1560
B-29	Ruth	Side-in 2800	F-47	Harry	Nose-in 2300	Climax	Nose-in 1850
B-29	Simon	Side-in 6200	F-86	Harry	Nose-in 2300	Climax	Nose-in 1850
B-17	Encore	Nose-in 4450	F-47	Harry	Side-in 5300	Climax	Side-in 2100
B-29	Encore	Nose-in 4450	F-47	Harry	Side-in 5300	Climax	Side-in 2300
B-45	Encore	Nose-in 3700					

TEAPOT

2.8b Two unmanned T-33 aircraft were equipped with instrumentation by Air Force Special Weapons Center (AFSWC) to measure gamma dose rate and integrated dose were used to make 7 penetrations through clouds resulting from 5 tests. Penetrations were made at times of 17 to 41 minutes after detonation and at altitudes of from 29,000' to 40,000'. Maximum dose rates of 1,800 r/hr were encountered, with the maximum dose received being 17 r.(Banks 1955: 5, 11)

5.1 From the DoD perspective, "The most important and critical single project of Operation TEAPOT was Project 5.1 (by WADC), which utilized three drone aircraft to investigate the lethal effects of blast on aircraft structure in flight". (DASA 1960a: 83) This project was part of the intensive study then underway regarding the use of atomic warheads for continental air-defense. It was necessary to determination the nuclear yield necessary to destroy an enemy aircraft or missile. In the planning for this project, it was decided to use the F-80 drone because "it was the only available proven jet drone". (Purkey 1958:12) MIT conducted an analysis to determine the conditions for destruction and near destruction of the F-80. A single-peak, ideal shock wave was desired without reflections or other spurious signals which would lead to complex effects on loading and resonance. A single peak shock would also be representative of an antiaircraft detonation at altitude.(Purkey 1958a:12)

A surface burst would eliminate reflections, but the yield would need to be about 10 kt (kilotons) in order to provide a lethal range large enough to accommodate the accuracy of drone positioning. The AEC would not approve a surface burst of this size because of fallout issues such as those discussed earlier in preparation for JANGLE. "Operational problems* eliminated the possibility of using a high air burst for the conduct of this project." The remaining possibility was for a relatively low tower shot, if the expected reflected wave could be eliminated or reduced.(DASA 1960a: 83)

Results from UPSHOT-KNOTHOLE "indicated that the reflected wave might be greatly accelerated during its passage back through the region heated by the fireball." (ibid., 83) It was thought that perhaps this acceleration could cause the reflected wave to merge with the incident wave in the region directly over the burst; a single shock would develop; and test conditions would be suitable for Project 5.1. (ibid., 83) The height of the tower was to be the lowest permissible for the yield used in consideration of off-site-fallout restrictions. The

yield was specified to be greater that 20 kt, to meet the operational limitations of position errors of the drone.(83) A simple development nuclear device having a yield of 28 kt on a 400' tower was chosen for this shot, MET. (ibid., 83)

Projects 1.1 and 1.2 measured free-air pressures on Turk and Apple 1 to validate the predictions made for MET regarding where the reflected and direct shocks merge into a single shock. The results "--suggested that, even if the reflected shock did not truly merge with the incident shock directly above the burst point, it would be of sufficiently low amplitude that the drone project could be conducted satisfactorily—"on MET.

Purkey (1958a: 42) makes an interesting point about the importance of this project. Since the conditions of MET "were tailored to the requirements of Project 5.1, the authority to recommend delay or postponement of the shot was given to the Project Officer". He came very close to using this seldom granted authority.

Four QF-80 aircraft were modified as drones and extensively instrumented. Their planned positions at detonation were: #1 would encounter light damage, capable of continued flight; #2 severe damage with possible failure; #3 so severely damaged that it would not support normal flight load; and #4 a spare. To recover the recorded data in the event of either remote-control or primary power failure, a jettisoning system was devised to which could be operated by the near-by director aircraft.(Purkey 1958a: 13-17)

Each drone was assigned two manned DT-33 director aircraft which were flown near-by for control during the test. One director aircraft maintained control while the second served as a spare. Each drone had its own flight pattern. When the drones approached GZ, control was transferred to the CP. The director aircraft regained control after passage of GZ. Each drone was assigned 2 chase aircraft that would shoot it down, if necessary; and they provided photographic coverage of the drones after the test.

A dry run of the telemetery system and instrumentation was successfully conducted on Bee by Drone #3. Purkey (1958a: 45) describes project execution on MET:
"Drone 1 made a successful takeoff but went out of control shortly thereafter and crashed." Drones 2 and 3 took off on schedule at 2 minute intervals. By this time, the spare drone was readied and started its takeoff run. "Just before the flying speed was attained the director flamed out on the runway." "Drone control was transferred to the director for the original Drone 1 –". The spare drone "became airborne successfully, but not before it had veered off the runway, jumped a ditch, and traveled about 300 feet across the desert". After this eventful takeoff, "all drones were under complete control and entered the flight pattern satisfactorily."

Free-air-shock photography showed "a relatively clear reflected shock merging with the incident shock approximately 2,600' above burst zero". "The coalescence of the incident and reflected waves extended over a 1,000' radius about the vertical through air zero". The lowest drone was at 3,800' above burst zero. (DASA 1960a:84)

5.2 WADC extensively instrumented two F-84s that were manned and flown on Turk, Bee, Apple 1, MET, and Apple 2. One was flown on Hornet. One craft would be positioned such that thermal radiation on the undersurface of the wing would cause temperature rises of at least 75° F. The other would receive gust loads no greater than 80% of limit.(Purkey 1958b: 5, 41)

5.5a The horizontal stabilizer assemblies of six F-80 and three F-86D aircraft were exposed on the ground during MET at 5 locations. These exposures provided WADC information about the stabilizer's response to airblast and gusts and were to be used along with in-flight data to determine the lethal airblast volume these aircraft would need to avoid for safe bomb delivery.(Whitford 1958, 5, 17)

5.5b "To supplement information on the thermoelastic response of basic aircraft structures, WADC instreumented an aluminum box beam for temperature and strain. The box beam was exposed during" MET. It was 42" long with a 7" x 3 ¼ " rectangular cross-section. It was placed in a blast shield, 4,000' from GZ and mounted 5' above the ground.(Hovey 1958: 5,15-6)

8.1 Three AD type aircraft were instrumented by NBA to study the contribution of thermal energy reflected from the earth's surface to the total thermal energy received by the aircraft during a delivery mission. Participation was on 5 shots.(Kviljord 1957: 3, 19)

8.4a NRDL measured physical characteristics of the thermal radiation received by the HA delivery aircraft. At shot time, the B-36 aircraft was located at an altitude of 46,775' MSL (mean sea level) with a slant range of 21,500' ± 300' from the point of detonation and was traveling at 294 mph. "All equipment performed satisfactorily."(Day 1958: 5)

<u>PLUMBBOB</u>

5.1 The Navy was planning the use of helicopters for delivery of a nuclear weapon against submarine targets. The HSS-1 used in this project was the first helicopter instrumented to obtain experimental results at NTS. Pressure-time and strain gages were installed by NBA. Participation was on 8 tests, most of which took the blast tail-on. UHF radio communication was used between the pilot and a controller to position the helicopter at zero time.(Walls 1960: 5, 11,18)

5.2 This project was conducted by NBA, the Aeronautical Structures Laboratory (ASL), and the Naval Air Material Center (NAMC). The military planned to use airships for the delivery of the Mark 90 and Lulu Anti-Submarine Warfare (ASW) special weapons. The nuclear effects that define the safe escape distances for delivery of these weapons by airship are initial nuclear radiation and blast. The objective of Project 5.2 was to determine the response characteristics of the Model ZSG-3 air ship when subjected to a nuclear detonation in order to establish criteria for safe escape distances. The results would be generally applicable to all other airship types. This project provides a good example of how things can unexpectedly "go wrong" during a field test operation.

Under the original project plans, two Model ZSG-3 airships (K-46 and K-77) were fully instrumented for participation in a total of 15 shots during Operation PLUMBBOB. K-46 was to be used only for moored tests on the ground and K-77 was to be used for in-flight exposure tests only.

Instrumentation was installed in the test airships. Airships K-46 and K-77 were instrumented in an identical manner and contained the most extensive instrumentation. Owing to time limitations, Airship K-92 was not so extensively instrumented, and Airship K-40 was the least instrumented. Each type of instrumentation was generally installed in more than one location on the airship. The types of instrumentation used were: strain gauges, pressure transducers, overpressure transducers, absolute pressure transducers, linear accelerometers, angular accelerometers, attitude gyros, shock-arrival indicators, position indicators, thermocouples, calorimeters and radiometers. The recording of data took place within the airship. High-speed motion-picture cameras were also set up on the ground adjacent to the test position to photograph the dynamic behavior and response of the airship during passage of the shock wave.

In April 1957, K-46 was flown from Lakehurst, NJ to NTS. Two days after arrival, K-46 was destroyed when it was torn from its mooring mast on Yucca Lake by a violent windstorm. Instrumentation was recovered and used on K-92. At the end of May,the K-77 was flown into NTS and was moored to the mast at a horizontal range of 18,200 feet from GZ for shot Franklin. Following the passage of the shock wave, K-77 became detached from the mast due to failure of the mooring cone and could not be re-moored. K-77's instrumentation equipment was not damaged.

K-92 was flown to NTS two days before the scheduled date for Shot Wilson. The firing date was repeatedly postponed; and 7 days after arrival, K-92 was destroyed when it was torn lose from its mooring mast at Yucca Lake by a dust devil of considerable energy. All instrumentation equipment was recovered without damage.

Finally, K-40 was assigned to the project and equipped with limited instrumentation. It was exposed to Stokes as a free balloon at a level attitude approximately 300 feet above ground. Mooring lines were released about 20 seconds before shock arrival to obtain free-body response data. Immediately following shock arrival, the envelope ruptured forward of the car, and the airship crashed but did not burn. Instrumentation equipment was salvageable with only minor damage. (Gilstad and Wheeler 1960)

The scope of data obtained was not adequate to predict the critical-response parameters for airships. (DASA 1960d) However, it is clear that the instrumentation used was indeed rugged!

After Stokes, Bill Ogle reported the following:
"Perhaps one of the most outstanding effects measurements in Nevada from the point of view of the outsider was the experiment intended to be an observation of the effects of the blast wave from (a) nuclear detonation on blimps. ---- It was important that the wind be blowing in the right direction since it was intended that the blimps be head-on to the shock

wave. ---- The expectation was that since the surface of the blimp was fairly flexible, the shock wave would pass through the gas inside the blimp just canceling the shock wave pressure outside, and that no particular damage was to be expected. However, as anyone could have told them, but no one did, the velocity of a shock wave is different in helium than it is in air. Specifically it is faster. Therefore, the shock entered the front end of the blimp as expected, but by the time it had reached the rear end, the shock wave inside the blimp was appreciably ahead of the shock wave outside. So the entire pressure differential was exerted against the rear end of the blimp and blew it right out, with the concomitant effects on the airworthiness of the machine." (Ogle 1985: 96)

5.3 This project by Naval Air Special Weapons Facility (NASWF) instrumented two Navy FJ-4 delivery aircraft that were manned during flight to test their response and acquire data during delivery-like maneuvers. One FJ-4 was on Boltzman, Hood, Diablo, Kepler, and Shasta and both were on Doppler and Smoky, during which one craft aborted. They were tail-on to the blast at the time of shock arrival.(Julian 1960: 17-20)

5.4 The response of an A4D-1 aircraft to thermal and airblast was measured during 7 shots. The nuclear environment external to the craft was also measure. These flights resulted in a significant amout of usable data for NBA and North American Aviation.. (Walls 1958)

5.5 John was a full-up test of the Airforce's F-89-1 capability for delivery of an air-to-air rocket with a nuclear warhead. Safe delivery and escape maneuvers for effective delivery of the weapon were being studied by WADC. An instrumented F-89J flew formation with the F-89-1 delivery aircraft for this project. At launch time, the instrumented F-89J and the delivery aircraft banked in opposite directions, and each performed a typical escape maneuver. This instrumented F-89J also participated in 13 other shots in various positions wrt GZ at the time of shock arrival: directly over, approaching, tail-to, and side-to.(Stalk 1960: 4, 11, 19)

6.5 investigated "the effects of radiation on the operational and structural characteristics of components, materials, and systems of the Nike Hercules guided-missile system". Personnel from the White Sands Missile Range and Bell Telephone Laboratories participated on 9 shots during which they also investigated the effects of a nuclear detonation on radar signals.(Harris 1981b: 139)

Ab. Foxholes

BUSTER

2.6 Two-man foxholes were constructed at 8 ranges from GZ on Baker, Charlie, and Dog. At some of the ranges, a half-size foxhole and a concrete covered foxhole were also constructed. "Total gamma and fast and slow neutron dosages were measured in several of the fortifications –" by Engineering Research and Development Laboratories (ERDL). Sulfur samples were used for fast neutron dosages, and gold foils were used to measure slow neutron dosages.(Walsh 1952a: ix, 6,12-15)

JANGLE

2.3-2 Standard two-man foxholes were constructed at 500' intervals from 2000' to 5000' from the Sugar and Uncle GZs. Each foxhole was instrumented by ERDL with 11 gamma film detectors to measure gamma exposure. One-man foxholes were also at 3000' and 5000'.(Walsh 1952b: 1-3) Foxholes would also be instrumented in a similar manner during future operations. However, the emphasis of these projects was more directed toward measurements of nuclear environments than on the fox holes themselves. Descriptions of such projects in fox holes are found in those technical areas related to the measurements made.

Ac. Water Tanks

BUSTER

3.9 On Easy, four US Army 3000 gallon rubber coated nylon fabric water tanks filled with drinking water were left uncovered and exposed at distances of 2000, 3000, 4000, and 4291 yards from GZ. The tanks were essentially undamaged and the water was essentially uncontaminated. Canned samples of sea water in various dilutions were also exposed to Easy at distances of 500 to 1000 yards from GZ. These sea water samples showed considerable induced activity. (Lindsten 1952a: vii)

JANGLE

6.8 The same water tanks as used on BUSTER were used on Sugar. Four of them were exposed uncovered at distances of 500, 925, 1500, and 2030 yards from GZ, and one was covered at 500 yards. All tanks withstood the burst. Water purification equipment for measuring induced activity over time was evaluated, but the water in the tanks first had to be contaminated to make the evaluations.(Lindsten 1952b 1-5)

Ad. Forest Fuels

BUSTER

2.2 Fire storms ignited by a nuclear explosion could create destruction long after the direct energies from a nuclear bomb have arrived. To obtain information about the combustion of forest fuels, prepared fuel beds of grass, punky wood, pine needles, and hardwood leaves were arranged in trays 2' x 4' x 4" deep. The tops of the trays were placed flush with the ground at 6 locations on the last 4 BUSTER shots.(Brown 1952: vii,4, 8)

TUMBLER-SNAPPER

3.3 provided the startling sight of conifer trees in the desert. The Forest Service wanted to predict atomic blast damage to forests and to establish relationships between blast parameters, tree motion, and damage. Four pine trees of about 45' height and 1' diameter, from the Mount Charleston area, were placed in concrete foundations, at each of four stations, located 5,000', 6,000', 7,000', and 8,000' from GZ. Emplacement took place at the 2 stations closest to GZ prior to Baker and at the 2 farthest stations prior to Charlie. Each of the stations also had a lollipop: a 4" aluminum I-beam in a concrete foundation which held a 32" diameter disk weighing 380 lb at a height of 14'. A lollipop was considered an "ideal

reproducible tree". The trees were spaced to observe individual trees rather than a group or forest.(Brown 1953: 3-4, 19)

At each station, one tree and the lollipop were instrumented for strain-time and for maximum strain at heights of 1' and at the base of the crown of the tree. Motion pictures were also made to obtain deflection data. This project focused on field-test methods and measurement techniques. It was in preparation for the next tree test on UPSHOT-KNOTHOLE that used a strand of trees. (ibid.: 3,9)

8.1 examined the minimum thermal energies required to ignite common forest fuels. Also the effectiveness of the blast-wave on flaming or extinguishing the ignition was sought. Fuel beds in trays 2'x2'x2" deep were prepared of conifer needles, hardwood leaves, grasses, and rotten wood for exposure on Charlie and Dog at 13 stations. (Arnold 1952: 3, 8, 15)

UPSHOT-KNOTHOLE

3.19 provided an even more startling sight than TUMBLER-SNAPPER 3.3. A tree stand covering approximately 1 1/4 acres was exposed to Encore and Grable. The trees were obtained from Lees Canyon on the Charleston Ranger District of the Nevada National Forest at an elevation of 8500'. The focus was offensive (on targets), so the trees were selected to be ponderosa pine trees of diameter, height, and arrangement typical of a "small managed western European woodlot." European woodlots are characterized by their uniform spacing and the absence of undergrowth and dead limbs. (Between Encore and Grable, debris was cleared from the stand.) The 145 trees were placed in concrete foundations and were planted in a uniform staggered row pattern at 20' intervals which covered an area 160' wide by 320' long, parallel to the blast line with the center of the strand about 6400' from the intended ground zero (IGZ). The trees averaged 51' in height and 15" in diameter at their base.(Sauer 1954: 3, 21-23)

To span environments from substantial damage to no damage, 2 duplicate lines of trees were also installed. The 2 lines were 100' apart and ran radial from GZ, between 5,000' and 8000', with trees planted at 500' intervals. Two pine trees were also placed at 1500' from GZ to determine over-damage; and two, the only broadleaf trees planted, were placed at 5500' and 7500'. A pair of pendulums was placed at 5000' and 8000' adjacent to the tree line. These pendulums represented an idealized tree system similar to the "lollipop" used in TUMBLER-SNAPPER, but they had substantially longer periods.(Sauer 1954: 23-28)

Prior to Encore, the natural period of each tree was obtained. Static and dynamic pressure was measured within the stand. Tree stem deflection was measured near the center of pressure of each tree crown for every tree, except the 2 at 1500'. Strain and acceleration and maximum strain were measured on 3 trees. Wind velocity and direction were also measured. Photography consisted of: 3 cameras 240' to the side of the stand to record tree motion; 2 cameras located 610' to the side were for the time-displacement of water vapor and smoke formed by the thermal pulse; and extensive still photography of pre-and post-shot activities and conditions was taken. This was the last tree project at NTS. (Sauer 1954: 28-34)

Ae. Minefield Clearance

BUSTER

3.5 The Army used its Universal Indicator Mine* to determine the probability of detonation of anti-tank mines when they were subjected to a nuclear explosion. [*Footnote: the Universal Indicator Mine does not actually detonate as does a real anti-tank mine, but its fuse provides a measure of the maximum displacement of the pressure plate of the mine. Most actual mines behave "enough like" the indicator mine that these results could be used for them.] Beginning at the intended ground zero (IGZ) for Baker, Charlie, and Dog, and extending 6000' east, a path 65' wide was bulldozed. Twenty positions were selected along this path at which 20 mines each were placed (two rows of 10 mines 5' apart). Between shots, new fuses and pressure plates were installed as needed, and the exposed fuses were returned to the laboratory for measurement. For Easy, the Indicator Mines were placed farther north, and only 4 positions were used.(Thurston 1952: ix, 1-2, 43-4)

Results showed that the mines exhibited a response to atomic detonations "which did not obey the scaling laws that had previously been established at HE tests". (Richmond 1953:11) Contrary to HE results, on BUSTER: 1) buried mines often had greater responses than corresponding surface mines; and 2) the response of a mine to a given peak pressure was often much less.

TUMBLER-SNAPPER

3.4 To verify and interpret the BUSTER 3.5 results, Universal Indicator Mines were placed along a minefield strip between 300 feet and 6,000 feet from ground zero and were exposed to Baker, Charlie, and Dog. Results confirmed the BUSTER results. The principle cause of the anomalies was attributed to the differences in shape between the HE and nuclear pressure-time airblast curves*. [*Footnote: Nuclear airblast curves were showing much longer rise times and lower peak pressures than HE.](Richmond 1953: 3, 11)

UPSHOT-KNOTHOLE

3.18 TUMBLER-SNAPPER showed that the long precursor wave associated with some nuclear explosions caused the rapidly responding Indicator Mines to react, in some cases, as if they had been struck by a static load rather than a shock load. On Grable, 1200 live mines and 2000 Universal Indicator Mines were exposed in a strip 620' wide running parallel to the Minefield Line of pressure gages which were placed from GZ+600' to GZ+2700'. These pressure gages would provide the shape of the nuclear wave which could be correlated with the response characteristics of the mines being exposed.

Three types of live mines were used: M6 (12 lb TNT) and M15 (22 lb Composition B) both of which are antitank mines and M14 (1 oz of tetryl) antipersonnel mines. The antitank mines were in arrays of 6x5 spaced 18" apart. Each of the 5 lines of 6 had each mine at a different depth: surface, 1", 3", 6", 9", and 15", and the panels of 30 were located at 250' intervals. The antipersonnel mines were also placed in panels of 30 at 250' intervals, at the surface with 6" spacing. The inert Indicator Mines were placed in panels of 6x10 with 5' spacing at 100' intervals.

To directly assess whether the nuclear pressure wave affects the pressure wave from a detonating mine, a rosette pattern was developed with a live M6 Mine (that would detonate) surrounded by Indicator Mines. This rosette pattern was used in a HE test prior to Grable as well as during Grable.(Richmond 1954: 15-21) It was found that results from HE tests could not be used directly to predict the response of live mines under nuclear blast waves. Correlation of the detonation characteristics of each type of mine and the nuclear blast wave was required. (Richmond 1954: 48-9)

PLUMBBOB

6.1 Fifteen mine types from the US and foreign countries: England, Denmark, Italy, USSR, Belgium, Germany, and France, were exposed on Priscilla. The total number of mines tested was about 115 which were laid out in an array of 15 arcs with ranges from 1250' to 5320' on the NE side of GZ. Along these arcs, about 56 BRL self recording pressure-time gages were placed. Between 920' and 1120', a rectangular array of inert mines and another array of live mines were laid. In addition, England had 4 special projects. Generally, the mines were laid at distances where the overpressure was such that it would cause a predicted 10, 50, and 90 percent probability of actuation. Some were also laid at different Depth of Burials (DOBs). Emphasis was placed on determining: 1) Reliability of predicting actuation, 2) Effect of DOB, 3) Extent of sympathetic actuation*, and 4) Whether special methods were needed for prediction of mine actuation in the precursor region.[*Footnote: Sympathetic actuation is the actuation of a mine caused by the explosion of another mine.](Deeds 1960: 5, 13-4, 16-7, 21, 24, 27)

6.2 "Influence mine fuzes" can use one or more of a variety of signals to sense the presence of their target, for instance seismic signals from a tank. Influence mine fuses that used seismic and magnetic signals in anti-tank mines were under research and development by Diamond Ordnance Fuze Laboratory (DOFL). It was "necessary to ascertain whether the variations in the magnetic field from an atomic detonation" could cause the mine fuze to detonate or alter the fuze's sensitivity to the magnetic field of the target. This project was conducted to provide data of the magnetic field component of the electromagnetic field from a detonation as a function of time and distance.

Five instrument stations were installed in Yucca Flat for Hood, Lassen, Wilson, and Owens and 5 in Frenchman Flat for Priscilla. In addition, 2 stations were installed for Diablo in Yucca. The instrumentation was shielded which resulted in it being large and bulky.(Haas 1962: 5, 11, 28, 44-6)

Af. Textiles and Clothing

BUSTER

2.4a Different fabrics, generally used in uniforms, were exposed on Baker and Dog. This project was similar to an exposure made during RANGER. Passive thermal indicators and photography were used.(Davies 1952: ix)

2.4b developed special techniques to prepare samples for field exposure on panels. Samples consisted of: 15 different plastics, 7 coated fabrics, 10 packing materials, and paints*. [*Ten different primer coats of paint and 9 different finish coats were applied to steel, wood, aluminum, and manganese panels.}

The panels were placed on racks that were being developed and built at the Army's ERDL. They were like a saw horse, 5' x 10' with two 3' x 5' panel sections that could be placed at any angle from 90° to 180°. "They are inexpensive, light, but sturdy racks anchored by steel stakes and require only 6 to 8 man hours to erect in the field. "The racks were placed at distances of 2, 4, 5, and 7,000' from the Baker IGZ and at 2,5, 7, 9, and 12,000' from the Dog IGZ.

The panel sections with their exposed objects could be removed from the racks quickly and easily. After BUSTER, the rack design was modified so that after the thermal flux, the rack would drop down with a shield covering the exposed panels before the arrival of the blast wave. This improved design would be used extensively throughout atmospheric testing for a wide variey of exposure specimen.(Miller 1952: ix, 4, 27-37)

<u>JANGLE</u>

6.3-1 To determine whether Army Chemical Corp protective clothing prevented radioactive dust from contacting the skin of the wearer, 4 activities were conducted. 1) Ten items of Army Chemical Corp protective clothing were mounted on racks located 2,000' from Sugar and Uncle GZs. 2) During Sugar, clothing was exposed at the 5 crewmen's positions within each of two M26 tanks. The tanks had all hatches open and were located 2,000' from GZ. 3) Men walking, crawling, and riding passed through contaminated areas of Sugar and Uncle wore coveralls, drawers, undershirts, socks, gloves and boots of various types that were later evaluated for contamination. 4) To contaminate coveralls, a "controlled contaminator" (like a big tumble washing machine) containing coveralls and ¼ lb of dust (from near the Sugar crater) performed a 10 minute cycle. To test decontamination procedures, the contaminated coveralls were air blasted and laundered with detergent. (Hendrickson 1952: 1-5)

<u>UPSHOT-KNOTHOLE</u>

8.6 Previous work had been aimed at determining the degree of fabric destruction or burn. However, it was found that "the criterion of whether a fabric did or did not burn gave no conclusive indication of how much heat was transferred to the backing" – and on to the person wearing it. On UPSHOT-KNOTHOLE, The focus of work changed "from determination of fabric damage to determination of thermal transfer through fabrics".

This extensive project consisted of 6 parts:

1) Military clothing with various weights and numbers of layers, included were: the pig uniforms of Project 8.5, cold weather uniform fabric assembles, under wear fabrics, boot materials, body armor, poncho material, and aluminized duck fabric.
2) Different percentages (including 0%) of synthetic-wool blends.
3) Surface reflectance and spacing between fabric layers.
4) The effect of exposure area size on thermal transfer.
5) Determine whether fabrics can be set on fire by the thermal energy from an atomic bomb.
6) " --- miscellaneous items of military interest"

On Encore and Grable, exposure racks were used for each of the first 5 parts of the program. On Encore, 8 distances betweem 2,110' and 9,000' were used for racks

addressing parts 1, 4, and 5. On Grable, 7 distances between 2,170' and 6.870' were used for racks addressing parts 2, 3, 4, and 5.

The racks consisted of 15 individual panels (3 horizontal rows of 5) that contained the fabrics to be exposed. A total of 35 racks with about 525 samples were exposed. The racks were metal, and each fabric sample was placed in a wood oak frame. "The actual exposure area was 9" x 12", with one-half of the wood backing in contact with the overlying test material and one-half spaced ¼" away. The rack permitted the fabrics to be positioned perpendicular to the incident radiation. At the end of the thermal pulse, to protect the panels from the blast wave and its debris, the rack released the panel portion which then fell to the ground lying in a horizontal position that protected the panels from blast.

For Part 6 of the program exposed:
1) Chemical Corps items, including: mylar and sateen fabrics, gas mask material, and gas mask face pieces were exposed on Grable at 5 distances.
2) Packaged Quartermaster items, including: standard packs of QMC 5/1 rations, bale packs of clothing, and fiberboard boxes of clothing were exposed on Grable at 4 distances.

The Quartermaster Corps had developed "paper thermometers*" which were used in these exposures and other projects.[*Footnote:"paper thermometers" consisted of black absorbent paper coated with a thin layer of a pure organic chemical that had a specific melting point. When the chemical melts, it is absorbed by the paper, exposing its black color. A black paper is proof that the organic coating had attained a temperature at least equal to its melting point. Melting points between 54°C to 305°C were available.](Feldman 1955: 3, 15-22)

PLUMBBOB
8.2 used the silica –powder–filled urea formaldehyde skin simulant used in PLUMBBOB Project 8.1(in Section Ba). Six different configurations of military uniforms and the skin stimulant were assembled, exposed, and evaluated. For this project, on Priscilla, two major recording stations were instrumented at distances of 7,500' and 12,150'. At each of these 2 stations, 20 simulant units with embedded thermocouples were mounted at 7' above the ground on panels secured to the station structure. For Hood, there was one station at 10,500'. Data from the pigs exposed in 8.1 were also used in the evaluation. On Lassen and Wilson this project also made basic thermal radiation measurements for Project 4.1 (also in Section Ba).(Derksen 1960: 5, 11-13)

Ag. Construction Materials, Including Metals, Ceramics, Woods and Paints
BUSTER
2.3 determined if grooves in wood and other considerations of geometry and color of wood might affect thermal response. Mahogany and balsa wood samples of different diameters and geometry were exposed to thermal radiation at 6 ranges between 2,000' and 12,000' on Baker and Dog.(Robertson 1952:vii)

2.4-2 "--materials exposed included: treated and untreated cloths, fire retardant paint samples, woods of several geometric configurations –". Metal foils that were passive receivers for the measurement of the spectral distribution of the total radiation energy were

also exposed. These materials were fastened to panels 18" x 11½", and seven of these panels were mounted at each station located at: 2, 4, and 5,000' on Baker and at 4, 5, 6, and 7,000' on Dog.(Monahan 1952: 4, 8, 16)

TUMBLER-SNAPPER

8.5 "-- to determine the probability of primary fires being started" by a detonation in urban areas, four common structural elements of wood frame buildings were exposed to Charlie and Dog. The elements were: (1) a cubicle room; (2) right-angle corner between walls, (3) right-angle corner with cornice; and (4) roof.

The elements were strongly constructed and mounted to resist demolition by the blast in order to show only the incendiary effects. On Charlie, 31 elements were placed at 6 stations, approximately 6,000' to 16,000' from GZ. On Dog, 51 elements were placed at 9 stations approximately 4,000' to 13,000' from GZ. The room elements were furnished with curtains, furniture, and other items such as newspapers. In addition, a panel consisting of 6 types of common household fabrics was placed at the Dog 7,000' station.(Bruce 1952: 3, 9-14)

UPSHOT-KNOTHOLE

8.13 extended and confirmed work conducted during BUSTER. Fire retardant paints in white, olive drab, and navy gray were formulated at EDRL and used to paint panels of yellow popular wood. Five panels of each paint type as well as unpainted panels were exposed at each of 3 stations during Encore.(Miller 1953: 3, 15-6, 20, 25)

Ah. Missiles – Debris Generated From A Nuclear Detonation

JANGLE

4.5 In 1950, JANGLE (formerly code-named WINDSTORM), was being planned for Amchitka Island in the Aleutians where the near surface geologic material contains rocks and boulders. The issue of damage produced by missiles* generated by an underground explosion became of interest. [*Footnote: missiles here refers to objects present in the environment or debris generated by the destruction of objects in the environment which the detonation causes to become ballistic projectiles.] High explosive tests in 1951 at the Dugway Proving Grounds, showed that explosive generated missiles had large ranges. As a result a project was added to JANGLE to further explore the phenomena. Its objective was: "to obtain data on the range, size, and source location of potentially damaging missiles produced from a typical concrete highway or landing strip, and a typical concrete wall of a type that might be used in a small factory building of several stories."

Construction for this project, which was considerable, consisted of: A) Highway strips of concrete and B) Walls and Foundation. The strips and walls were to become the source of missiles. The Highway strips were located between 15 and 300 feet of GZ. The Walls and Foundations were between 18 and 54 feet.

The walls and foundation were within the postshot crater as were most of the highway targets*. To permit determination of the source location of missiles, the highway strips were poured in small sections with different pigment and aggregate; and the walls also contained

different pigmented sections. The collection areas for the missiles were extensions of the construction radials . They started at 1500' from GZ with a width of 26' and extended to 8500' where their width was 148'. [*Footnote: The report indicates the dimensions and materials (concrete and steel) of the walls and foundations. The author estimates that the walls and foundations added about 13% to the mass of the overburden in the area which they covered.]

The Uncle results indicated that a 25 kt penetrator weapon, which was then of interest to the Army, detonated at the same scaled depth beneath a concrete runway, would generate missiles that could damage or destroy buildings out to about 1000 feet or airplanes on the ground out to 3000 feet. However, airblast from the same explosion would damage buildings out to about 2200 feet and airplanes on the ground out to about 6000 feet. Therefore, it was recommended that "further study of the missile problem is not justified."* (Vaile 1952:1, 9,10,13,38) [**Footnote: While the DoD did not conduct further missile studies, the civil defense community pursued a number of projects to assess potential missile damage in the civilian sector. These projects are described in Chapter 2.]]

PLUMBBOB

4.3 Lovelace Foundation jointly fielded this project for the DoD and the Civil Effects Test Group (CETG) on Priscilla, Smoky, and Galileo. One hundred fifty-five traps with a "total missile collecting area of about 486 ft^2 were employed in open regions, shelters, and houses." Also, about 234 ft^2 of missile-absorbing material was cemented to walls in a shelter and in open areas. The effects of hill-and-dale terrain on missiles were examined on Smoky. The missiles were from window glass mounted in frames placed in front of the traps and from marked military debris; marked gravel; marked spheres; and native stone placed at various ranges in the field.(Harris 1981b: 130-132)

Ai. Military Vehicles and Ordnance

UPSHOT-KNOTHOLE

3.21 The following ordnance items (and the number of them) were exposed to "provide a means for a statistical estimation of damage" :
Trucks, 2-1/2 ton M-35 (27)
Trucks, ¼ ton M-38A1 (27)
Guns 57mm, M-1 (27)
Howitzers 105mm M-3
Guns 90mm AA, M1A1(2)
Tanks: M4 (3); M24 (1); M3 (3); and M7 (1)
For Encore, they were placed at 17 ranges between 1195' and 6550' from actual GZ; and for Grable, 19 ranges between 380' and 4380' were used.(Bryant 1955b: 3,75-7)

3.24 Six Landing Vehicles, Tracked (LVT's) were exposed during Encore and Grable. Five of the vehicles were LVTP-5's (LVTPersonnel – type 5) and one was a LVTH-6 (LVTHowitzer – type 6) on which the howitzer was not installed. The six LVT's were placed at 6 distances ranging between 775' and 4510' in Encore and at 6 distances ranging between 1030' and 3450' in Grable. Vehicle displacement was measured post-shot and a damage assessment made. Still photos were taken pre- and post-shot. The shielding afforded by LVT's from

prompt radiation was obtained by installing dosimeters on the interior and exterior of the vehicles.(Olson 1954: 3,14-7)

TEAPOT

3.1 Eight types of military vehicles were exposed on 9 shots:

1. ¼ ton truck, Old Type
2. ¼ ton truck, M38A1
3. 2 ½ ton truck, M35
4. 2 ½ ton truck M135
5. 5 ton dump truck, M51
6. Armored Infantry Vehicle, M59
7. Self-propelled, 155 mm gun, T97
8. Tank, 90 mm gun, M48

	Vehicle Type								
Shot	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Desert Rock**
Wasp	10	6	6	6	4	1	1	-	
Moth	-	3	3	3	2	-	-	-	
Turk	-	3	3	3	2	1	1	2	
Hornet	-	-	-	-	-	-	-	1	
Bee	16	-	-	-	-	-	-	-	
Apple	6	-	-	-	-	1	1	3	4*
Wasp'	7	-	-	-	-	-	-	-	
MET	33	5	-	-	-	1	1	3	
Apple2	14 vehicles, a mixture of Project 3.1 vehicles and Desert Rock								

* Trucks

On a given shot, whenever there was more than 1 vehicle of a given type, they were located at different distances from GZ.

On Bee, of the 16 trucks of ¼ ton, 8 of them were on asphalt and the other 8 on desert soil. On MET, vehicles were located on asphalt, sand, and water. A line of self-recording gages measured static overpressure and dynamic pressure. Also, Project 2.7 provided film badges for the shielding studies conducted inside the vehicles. After each shot, an evaluation of damage was conducted; and displacements of the vehicles was measured.(Bryant 1956: 5, 18-36)

PLUMBBOB

1.8b Fifty-one military vehicles, two M48 World War II (WWII) tanks and 49 other lighter weight vehicles (jeeps, ¼ ton trucks, and utility vehicles) not specifically identified were exposed on Smoky along Lines 1, 2, and 5. In addition, on lines 2 and 5, two revetments each were also constructed to examine the protection they would provide vehicles. They were simply an earth mound about 7' high, and a vehicle was placed side on behind each of the 4. The following table indicates the effectiveness of these simple constructs as well as of the different terrains .

In this table: Range in feet is followed by SO = side-on, or by FO = Front-on; Terrain is F = flat, REVET = Revetment, BOHILL = Bottom of Hill, (HILL, DALE, WASH, RAVINE and GULLY are just that); Damage: S = Severe, M = Moderate, L = Light, and N = none. There were two M48 tanks used. One was at 2840FO on Line 2, and the other was at 1231SO on Line 5.

Range (ft)	Terrain	Displace-ment (ft)	Dam-age	Range (ft)	Terrain	Displace-ment (ft)	Dam-age
LINE 1				2914SO	DALE	75	M
2381SO	F	630	S	FO	DALE	0	M
FO	F	430	S	3218SO	HILL	220	S
2760SO	F	150	S	FO	HILL	55	M
FO	F	150	S	SO	HILL REVET	0	L
SO	F REVET	0	L	SO	DALE	0	L
2943SO	F	115	M	FO	DALE	0	L
FO	F	30	M	3568SO	HILL	73	M
3406SO	F	110	M	FO	HILL	15	M
FO	F	25	M	3739SO	DALE	0	M
SO	F REVET	0	L	FO	DALE	10	M
3875SO	F	20	M	3874SO	HILL	110	M
FO	F	15	M	FO	HILL	20	M
LINE 2				4115SO	HILL	120	M
1966SO	HILL	7000 to 10,000	S	FO	HILL	18	N
FO	HILL	700	S	LINE 5			
2215SO	DALE	30	S	1231SO	F	15 (M48)	S
FO	DALE	20	S	1728SO	GULLY	0	M
SO	HILL	600	S	FO	GULLY	0	M
FO	HILL	600	S	1836SO	RAVINE	100 to 1,500	S
2548SO	HILL	1,000	S	FO	RAVINE	100	S
FO	HILL	800	S	2341SO	BOHILL	100 to 600	S
SO	HILL REVET	0	L	FO	BOHILL	60	M
2840SO	DALE	0	L	2425SO	WASH	800 to 1,000	S
FO	DALE	0	L(M48)	FO	WASH	800 to 1,000	S
SO	DALE	0	L	2975SO	GULLY	15	M
2890SO	WASH	225	S	FO	GULLY	5	M
2940SO	WASH	110	S				

Projects 1.8a and 1.8c provided their data for the analyses of this project which was used for the detailed descriptions of the damage provided in this project's report.(Bryant 1957: 4, 9-18)

2.4 had objectives in three areas:
I) To assess their neutron and gamma shielding, Ontos (vehicles), M-48 tanks, and hemispheres* were exposed on 4 shots. The 4 hemispheres used were 2' 8" in diameter. Two hemispheres were constructed of standard armor steel about 4" thick. The other 2 were constructed of a newer type of "cushioning" armor which was then being investigated. The "cushioning armor" consisted of two 2" thick pieces of 20% and 10% boron-loaded polyethylene between two 1" thick hemispheres of standard armor steel.]

SHOT	EQUIPMENT EXPOSED			DISTANCE FROM GZ (ft)
	Ontos	M-48 Tanks	Hemispheres	
Franklin	4	4	4	1800
Lassen	3	3	4	1800
Wilson	3	3	4	1800
Hood	3	3	4	3000

All equipment was instrumented with a complete set of radiation detectors. The tanks used detectors at the personnel locations, and swine were placed in some of the tanks.(DASA 1961a: 13, 18-22)

II) Structures that were constructed for Exercise Desert Rock VII were instrumented for neutrons and gammas on Priscilla: Five 7'x7' machine-gun emplacements, 10 two-man foxholes, 2 modified foxholes, 8 open foxholes with and without tunnel revetments, two 6'x8' "hasty shelters", and two locations with free field measurements. Four ranges were used: 477, 573, 760, and 1300 yards.(ibid. 65-68)

III) Neutron and gamma attenuation studies in soil were performed by putting samples of Area 7 soil in a container and placing them on Owens along with the cubic yard sized samples of Project 2.1. These samples, unlike the 2.1 samples, were instrumented with detectors.(ibid. 37, 39-40)

Aj. Fireball Exposures, ICBM Studies

TEAPOT

5.4 This significant project consisted of two parts: lethality and Thermal-Shock within the fireball.

1) Lethality exposures within the fireball -- On MET, solid spheres 10" in diameter and hollow cylinders 10" long and 5" in diameter were exposed atop lightweight television towers at 5 ranges within the fireball. The spheres were of 3 types: solid steel, solid aluminum, and aluminum with ceramic inserts. The hollow steel cylinders had different wall thicknesses ½", 1", 1 ½" and 2". For identification, a numbered slug was inserted in the center of each specimen. Also, the specimens were made of different but closely related compositions. If only a fragment of a specimen was retrieved, chemical analyses could identify the specimen.

Location	Tower Height (ft)	Ground Range (ft)	Steel Spheres	Aluminum Spheres	Ceramic Insert Spheres	Cylinder Wall Thickness (in)	
						Left*	Right*
Tower	400	12.5	X	X			
1	348	60	X	X	X	2.0	2.0
2	296	120	X	X	X	2.0	1.5
3	244	180	X	X	X	1.5	1.0
4	192	240	X	X	X	1.0	0.5
5	140	300	X	X	X		
1 (base)	0	60	X				

(* Facing GZ)

One steel sphere and one aluminum sphere were positioned in the corner of the shot cab at a range of 12.5 feet from the weapon. These were the only specimen not recovered postshot. The numbered slugs were recovered in every specimen making chemical analyses unnecessary. (Kester 1958:18-21).

2) Thermal-Shock exposures outside of the fireball --- Small samples of various materials being developed for possible use as protective surfaces on ICBMs were mounted as thin flat plates at ranges external to the MET fireball: 1,100', 2,200', 3,100', and 6,500'. To obtain high thermal intensities, exposures need to be close to the nuclear explosion. But, blast forces are also high close to the explosion. Two innovative techniques were used to reduce the effectiveness of the blast. At 1,100' and 2,200', a support structure of delta-wing design was used. For the 3,100' and 6,500' ranges, a parabolic reflector was used to focus the thermal flux in order to obtain extremely high fluxes over a small area at the focal point.(Kester 1958: 5, 15, 18-21, 24-5, 28)

PLUMBBOB

8.3b This was a significant continuation of the DoD's efforts within the fireball that were begun on TEAPOT. This work would be directly applied to the structural vulnerability of ICBMs. This project is in two parts. Part 1 which involves the field work, is discussed here. Part 2 used the data acquired in Part 1 to address ablation, and it is not described here.

Part 1 proof-tested instrumentation for making measurements within fireballs and acquired information on thermomechanical effects, including ablation. On Prisicilla, at 100' from GZ, an electrically instrumented plastic sphere with a time-history instrumentation system to be employed on Smoky, was exposed above a hole. The hole was 8' deep and was half refilled with loose dirt to soften the impact of the specimen after its exposure and the destruction of its exposure mounting. Post shot Prisicilla operations began on 3 July, (D+9) when the radiation level at GZ was 200 mr/hr. The plastic sphere was not found intact, but its major components were recovered from 200 to 600 feet from their original position.(Cosena 1961:17-19)

On Smoky, 24 specimen were used. The specimen at 1,380' was not within the fireball region, and it was buried 1' below the surface. It was exposed only to neutrons. The other 23 specimens were within the fireball.

Two cylindrical specimen were attached to the shot tower and oriented toward the burst point. These cylinders looked like missiles with one end aerodynamically designed like a nose cone. One was 15" in diameter and 7' long and weighted 2,300 lbs. It contained 2 tape recorders and peak pressure and velocity-distance-impact* gages. [*Footnote: The velocity-distance-impact gage had a movable plunger of hardened steel and a target block of soft aluminum held in a tube. The plunger was positioned in the tube but free to move within the tube. The tube was placed in a preset distance from the ground (on the shot tower oriented toward the blast point). The detonation accelerated the tube in a direction along the axis of the tube. When the tube impacted the ground, the plunger penetrated the target block, and the amount of penetration of the plunger into the block was a measure of its velocity after it had moved the preset distance.] The other missile-like cylinder was 13.44" in diameter, 40" long, weighed 366 lbs, and contained 5 locations along the axis of the cylinder where inserts were placed. The inserts consisted of 20 different materials whose ablation characteristics were of

interest, and 4 inserts were placed in each of the 5 locations of this cylinder.(ibid., 31,35) Inserts were also used on other specimen, see following table.

The remaining 21 specimen were supported by the cable system of 5 independent cables. Four of the cables were connected to deadmen at a range of 800', and the fifth at a range of 2,200'. "The cables were directed over pulleys near the top of the shot tower and down the outside of the tower through additional pulleys near the ground". This allowed for the specimen to have the range and orientation desired.(ibid., 19-20) The 21 specimen were:

Slant Range (ft)	Location Cable #	Specimen*	Diameter (inches)	Weight (lbs)
		Smoky		
150	2	MI Steel Sphere	713	318
150	2	Insert Sphere	13.44	320
150	2	MI Sphere	13.44	230
160	Shot Tower	EI Cylinder	15x84 long	2.300
250	4	EI Steel Sphere	13.44	247
250	4	MI Steel Sphere	13	318
250	4	Inert Sphere	13.44	321
250	1	MI Bowling Ball	5	4
300	5	Iron Sphere	10	149
300	5	Zinc Insert Sphere	10	135
300	5	Titanium Sphere	8	44
300	2	Molybdenum Sphere	8	99
300	1	Stainless Steel Sphere	8	74
300	5	Copper Sphere	8	87
300	3	Plastic Sphere	8	17
350	1	EI Steel Sphere	13.44	247
350	1	MI Steel Sphere	13	318
350	1	Insert Sphere	13.44	320
400	5	Zinc Sphere	10	135
400	5	Zinc Insert Sphere	10	133
400	5	MI Bowling Ball	5	4
450	Shot tower	Insert Sphere	8x40 long	366
765	1	MI Sphere	13.44	38
1380	Underground 1'	Graphite Sphere	8	17
		Priscilla		
710	Ground	EI Plastic sphere	13.44	40

[*Footnote: MI – Mechanically Instrumented gages, like thermal intensity and peak pressure; EI – Electronically Instrumented gages, like pressure-time.(ibid., 21-23, 29-32)

All but one of the specimen were recovered post shot. The major recovery effort, however, was not conducted until approximately 5 months after Smoky due to the high radiation level. The tape transport system from 2 of the 5 tape recorders operated satisfactorily. Three tapes yielded signals. "The velocity-distance impact gages yielded apparently reliable velocity

versus distance data." "It is believed that the state of the art of recording fireball phenomena was advanced as a result of this test; however, it is believed the art of recording is not sufficiently advanced at this time to obtain usable data at a slant range of 160 feet or closer for a yield similar to that of Shot Smoky, using the instrumentation techniques employed during the shot."(ibid. 5)

Ak. Miscellaneous Other Exposure Projects

UPSHOT-KNOTHOLE

3.20 exposed typical items of signal communication equipment such as would be found in a communications zone or field array area. Equipment was placed at varying distances from GZ to obtain an anticipated damage spread from severe to negligible. On Encore, 93 test groups were used. On Grable, only 17 test groups were used "because of shortage of funds, material, and labor". Photographic records of damage and evaluation of damage were made by project personnel. (Eggert 1955: 3)

3.26 Petroleum, Oil, and Lubricant (POL) items were exposed on Encore and Grable. Two types of items were exposed:

Type I were items found at POL installations:

1. *Standard 55-gal storage drums, filled with diesel fuel oil* were placed in 4 stacks of 15 drums each arranged in triangular and trapezoidal shapes at 10 locations.
2. *Storage tanks 3' diameter x 8' high, filled with diesel fuel or aviation gasoline* were arranged in groups of 4 at 4 locations.
3. *Six vertical storage tanks (filled with water to 7' for Encore; water drained for Grable) of about 15' diameter and 8' or 10' high* were at 5 locations.

Diagnostics was mainly of motion pictures. Thermocouples recorded temperatures on some tank surfaces to correlate with the occurrence of fires. Pressure gages were used on one vertical tank. Exposure locations ranged from a couple hundred feet to nearly 15,000'.

Type II were items found at a POL supply point:

1. *Cans and drums of gasoline* were placed as they would be stored at a fuel dump.
2. *Cans and drums of gasoline* were protected by revetments, tie downs, and clamps.
3. *Collapsible gasoline storage tanks.*
4. *Can cleaning equipment.*

The items were stacked in various ways with various POL fillings and placed in 4 locations for Encore ranging from 3,100' to 10,200'; 4 locations were also used for Grable between 900' and 2,100'. Still and motion pictures were the diagnostic.(Sevin 1955e: page numbers missing due to declassification stamping)

3.27 Field medical facilities and their associated equipment were assembled and exposed during Encore. Two types of medical facilities were used: Unit A, a composite battalion aid station and regimental collecting station; and Unit B, a composite division clearing station, mobile army surgical hospital, and evacuation hospital. Both had 2 configurations: a standard aboveground (*) configuration and a dug-in (**) configuration. The objective was to

assess the degree of protection to the installation and personnel that was provided by a dug-in position.
At 4,163', 4 units: Unit A *, Unit A** , Unit B*, and Unit B** .
At 9,000', 4 units: Unit A *, Unit A** , Unit B*, and Unit B** .
At 15,000', 2 units: Unit B* and Unit B**.
Unit A was a standard squad tent. Underground construction for each Unit A** was an evacuation 34'4" x 16' x 4'6" deep. Unit B was divided into 4 separate tents: a surgical tent; a X-ray, dental, eye, maxillofacial, and ear, nose and throat tent; a pharmacy and laboratory tent; and a ward tent. Underground construction for each one of the 4 tents of Unit B** was 18' x 52' x 6' deep.

Both A and B units contained all representative items of equipment authorized for those units. They were furnished in detail with equipment to be fully functional. Some of the equipment was operational at the time of the blast. Electricity was obtained from a dug-in generator at each location.(Chapman 1954: 3-66)

8.11a "Twenty materials, prevalent in American cities and representing a wide range of thermal characteristics, were mounted in wood frames 2'x2'x3½" deep and exposed on Encore and Grable. The 20 frames were placed at between 6 and 9 distances from GZ where the predicted thermal energies bracketed the critical ingnition energies for the materials: rayon curtains, cotton, wool, flannel, denim, sheets, crepe paper, grass, cardboard, mop, broom, Venetian blind, wood, shredded newspaper, etc.

For Encore, 5 houses were erected:
- 3 "miniature" houses (6'x6' on concrete slab, frame construction, plaster wallboard, asphalt shingles, and gabled roof) with: 1) poorly maintained siding and a yard littered with weeds and trash; 2) better maintained siding and yard kept free of flammable trash; and 3) no trash in yard but considerable decay in wood siding.
- 2 "block" houses (10'x12' on concrete slab, sturdily constructed block, open 4'x6' window facing GZ) with materials placed in the interiors which were: 1) potentially fire-hazardous and 2) relatively fire-resistant. There was significant photographic coverage during the shot as well as pre and postshot. (Bruce 1953: 3, 15-26)

8.11b Previous operations showed that common building materials are not ignited by thermal radiation beyond the range of complete blast damage, but leaves, paper, and wood are ignited beyond that range. This project focused on the extent and distribution of primary ignitions of materials found in urban areas.
Exposures were made on Dixie and Encore of:
- 11 urban kindling fuels such as: newspapers, awning covers, wrapping paper, pine needles, fiberboard carton, etc., placed on frames, at 11 stations.
On Encore:
- Automobile seat coverings: boxes were filled with combinations of stuffing and covering materials, at 6 stations.
- 4 automobile seats were exposed adjacent to the filled boxes.
- 13 cars were exposed in a compact group.
- With FCDA, 18 cars were exposed in 6 groups of 3.

On Encore and Grable:
- 9 fence sections, 8 severely weathered and one of new lumber, were placed at 1 location. (Sauer 1953: 3, 17-22, 25-30)

TEAPOT

3.9 Four petroleum storage tanks which had remained substantially undamaged during UPSHOT-KNOTHOLE 3.26.1 were used; they were simply moved over to MET. The roofs were not restored because only the response of the tank shells was of interest. The tanks were all 80% filled with water, and were located on the desert sector only. They were not instrumented, but damage evaluations and photographs were made.

TANK DESCRIPTION	HEIGHT (ft)	Diameter (ft)	Ground Range (ft)
Bolted Steel	8	15.5	1,200
Welded Steel	10	15	1,350
Welded Steel	10	15	1,500
Welded Steel	10	15	2,100

(O'Brien 1957:14,15)

6.2 Equipment of the Signal Corps, electron tubes, radar, and crystal units, were exposed to the most intense gamma radiation fields obtainable that were consistent with the design of the units. The intent was to determine the extent of reliability of these units either in use or in storage at the time of detonation. Exposures were conducted on Apple 1 and MET at 2 ranges, 450' and 550', with the equipment in secured containers for protection against thermal and blast effects. Performance characteristics were evaluated pre and post test.(Graham 1957: 7, 8)

PLUMBBOB

6.2a A total of 60 semiconductor diodes and 293 transistors were exposed inside of wooden boxes. The boxes were made of heavy marine plywood which contained aluminum cans that contained the semiconductor diodes and transistors with sponge rubber pads between items. Gold foils which were used as indicators of the neutron irradiation were included in each box. On Priscilla, 12 boxes were used and on Hood, only 1. On Priscilla, 5 of the boxes were located at either 5" or 6" below the surface at ranges between 800' and 3500'. At 2100', 9 boxes were located in a single drill hole at depths between 5" and 8'. During the test, 45 of the transistors were in equipment that was operating.(Haas 1960: 5-6, 10-2)

B: BIOMEDICAL EXPOSURE PROJECTS

Ba. Animals

BUSTER

4.2 This project illustrates how a field project rapidly can become complicated. Dogs had been used extensively in laboratory studies of burns. On BUSTER, they were used for this purpose as well as to correlate laboratory and field studies. The dogs wore protective jackets with holes on the side of the jacket facing GZ. Two dogs were to be exposed on a trial run during Baker, which was scheduled for detonation at 0700. At 0630, the shot was postponed. Project personnel immediately proceeded to remove the animals only to find that

they had both succumbed to the elements. The army then took more elaborate protective measures against the cold.
- Two chemical heating pads were included in each dog jacket.
- All animal surfaces except for the exposure apertures were wrapped with aluminum foil.
- A 500-watt infrared lamp was focused on the exposure apertures of each animal.

Six dogs (3 at 7000 feet and 3 at 9000 feet from GZ) were exposed along the thermal line on (of course) shot Dog.(Brooks 1952: 5-14)

4.2a Sixty rats were placed, 15 each at 4 stations. The heavy-wall aluminum animal containers, that accommodated 5 rats each, allowed thermal radiation through a 0.9 or 2.5 cm diameter aperture. Burns on the rat's skin were studied and compared favorably with burns produced in the laboratory.(Sheline 1952: v, 3-6) This project and BUSTER 2.4-1, the thermal line project, used the same exposure stations that were located at 4, 5, 7, and 9,000' from the IGZ of Baker and Dog.(Sheline 1952: v, 3-6, 8, 33-4)

<u>JANGLE</u>

2.7 Dogs and sheep were exposed at 2500', 5000', and 8000' from GZ on both Sugar (12 ewes and 15 dogs) and Uncle (20 ewes and 23 dogs) in order to assess the hazard due to inhalation of dust and to compare the internal and external doses obtained by the exposed test animals. Most of the dogs and ewes were in individual wire mesh cages that were secured against blast by guy wires. Also, foxholes were built at 2500' and 5000' for both tests. On Sugar, 2 of the 15 dogs and 2 of the 12 ewes were in the 2500' foxhole, and 1 dog and 2 ewes were in the 5000' foxhole. Uncle had similar numbers. Inside the standard 2'x4'x6' foxholes was a plywood and mesh cage for each animal. Animals which had been exposed at 5000' and 8000' on Sugar and which had not been sacrificed were reused for Uncle. Animals were sacrificed between H+10 to H+24 hours and at D+2, +4, +9, and +70 days. Dry ashed homogenates of lung, liver, spleen, kidney, blood, bone, urine, and gut contents were assayed for radioactivity. Total gamma exposure had been obtained by JANGLE Project 2.3-1.(Smith 1952: ix, 4-8,45-48)

<u>TUMBLER-SNAPPER</u>

4.2 was a preliminary but extensive effort to "design, construct and evaluate instruments and equipment for the exposure of animals". " -- wooden dogs containing accelerometers were exposed in open mesh cages suspended above a protective barrier". These cages were held by arms that could swing. Slide wires guided the cage to a lower position behind the protective barrier. Three of these protective barriers were constructed for use on Easy (@ 1100', 1400', and 2100') and How (@ 1800', 2100', and 2600'). However, the wooden dogs were subjected to thermal radiation and flying missiles before reaching a safe position behind the protective barrier.

Another container tested for airblast exposures consisted of a simple cylinder, 26" in diameter and 48" long with end flanges, which was bolted to heavy timber skids and sandbagged in place. Peak pressure and pressure-time recorders were placed in 5 of these containers that were located where peak pressures between 30 and 10 psi (pounds per square inch) were expected on Charlie and Dog. These containers did provide

protection against flying missiles and thermal radiation. Some of these cylinders were modified to permit thermal radiation burns on swine, see Project 4.6.

Single-layered multiple compartment mouse cages were designed and evaluated for suitability on studies regarding lethal gamma ray dose. Mice were exposed in these cages at 5 ranges on Charlie and Dog.

The final part of this large program consisted of designing and testing nine "instruments or devices for use with animal exposure equipment" such as: timers, magnetic shutter release and photographic coverage, and improved battery power supply.(Draeger 1952: 11-5, 22, 30, 33, 35, 47-8, 58-73)

4.3 Mice were placed in a hemispherical cavity of 7" radius that was centered in a hemispherical shield which protected them against blast, heat, and the large gamma-ray fluxes but allowed the neutrons to enter. Exposures were conducted during Charlie, Dog, and How. Groups of 30 female mice were the norm at each location. Charlie used 8 locations between 1,396 and 1,713 yards from GZ; Dog's 5 locations were between 1,249 and 1,449 yards, and How's 11 stations were between 1,204and 1,703 yards. The weight of the spleen and thymus were determined for the animals that were sacrificed, and white blood cell counts were made.(NRDL 1980: 15, 18-9, 29, 39-43, 47-54)

4.6 used Chester White pigs (whose skin most closely resembles human) and focused on determining the time within which a skin burn was produced. Four pigs were placed in individual aluminum cylinders at each of 3 stations on Charlie and Dog. Shutters were designed that exposed 2 rows of 5 circular apertures with 1.5" diameter for different lengths of time. Results showed that the most sever burning occurred in the 0.1 to 0.2 sec time period, and there was little increase in the severity of a burn after 0.5sec.

To compare small and large area burns, an additional 4 pigs were placed at the farthest stations on Charlie and Dog. These containers had a central rectangular aperture 3" x 4.5" and 4 circular apertures 0.75" in diameter. Results showed no difference between large and small areas in terms of the severity of the burns.(Kingsley 1953: 3, 9,13-5)

<u>UPSHOT-KNOTHOLE</u>

4.1 A few minutes after zero time, two QF-80 drone aircraft each with two monkeys in restraining boxes and mice in wire cages were flown through the radioactive clouds at 28,000' and 30,000' on Dixie and 30,000' and 32,000' on Encore. The objective was to define and evaluate the hazards to which a bombing crew would be exposed while flying through a nuclear cloud. Measurements of gamma radiation intensity were made inside of the drones. Cloud sampling filters were used to measure the radiation exposures in the external cloud. The temperature of the aircraft skin and the change of pressure while passing through the cloud were also measured. "All animals were sacrificed in approximately 30 min after passing through the cloud to minimize biological fractionation and translocation."

A second method for determining conditions in the clouds consisted of dropping 10 parachute-borne canisters, 5 from each from 2 aircraft, containing telemetering facilities and film packs secured to their outside. On Dixie, the canisters missed the radiation cloud. On Encore, the bomb bay doors malfunctioned on one aircraft; and of the 5 canisters released from the other aircraft, only 2 provided data. Four film packs provided readings. (Langham 1953: 3, 15, 19, 28, 30-2)

4.2 To compare the blast injuries received by small and large animals, rats and dogs were placed within aluminum cylinders with open ends and covered with dirt to provide shielding from missiles and radiation. The 56 cylinders were oriented with their axes normal to the direction of the blast. The rats were placed in 18" x 18" x 5" cages which were divided into 25 compartments. On Encore, 8 cages of rats, about 200 animals, together with 16 pressure recorders were placed in exposure cylinders at 1340', 1410', 1470', and 1540' from GZ. For Grable, 28 cages, about 700 rats, and 56 pressure recorders were placed in 4 of the 8 exposure cylinders at each of 7 stations. Fifty six dogs were tethered, 2 each, in the remaining 28 exposure cylinders, 4 of which were also placed at each of the 7 stations located at: 940', 990', 1040', 1100', 1180', 1310', and 1500' from GZ. The 900 rats were "female Sprague Dawley rats weighing between 150 and 175gm. The 56 short-haired, mixed sex, hound-type dogs were within the weight range of 20-25 pounds" (Draeger 1953: 3, 11, 1316)

4.8 TUMBLER-SNAPPER and GREENHOUSE work had concluded that: "The biological effect of neutron radiation from large diameter implosion weapons is insignificant compared with the effect of the gamma radiation over the ranges of interest for gamma radiation." However, The neutron output from Grable would differ from the larger diameter implosion weapons previously tested.

To measure the biological effectiveness of just neutron radiation from Grable, mice were placed within hemispherical lead shields of 7" wall thickness that would eliminate their exposure to gammas. They were then placed at 6 foxhole stations and 14 ground-surface stations. The conclusions from this work were: "—the biological effectiveness of neutrons from the artillery shell appeared to be approximately one-half the measured gamma dose in roetgens, over the range of biological interest for the gamma radiation (200-1000 r)."(Carter 1953: 3, 13-4, 19-21, 49)

8.5 Laboratory experiments had recently shown that pig burns behind fabrics do not follow the same time-thermal intensity relationship as found for unprotected skin. Fabrics have a "heat reservoir" which stores thermal energy with a subsequent release to the skin. It was decided to conduct studies with clothed pigs. Chester White pigs were used "because the skin on the side of this animal has a close structural similarity to that of man and gives a comparable response to quantitatively similar thermal stimuli.

A trial run on Nancy used 8 pigs and was successful. For the Encore and Grable tests, the pigs were placed in animal holders with a web strap to hold the pig secure which passed under the pig inside the uniform. Three types of uniforms were developed, based on Army materials used in different climates: Hot-Wet, Hot Wet 50/50, and Temperate were used.

Each of these materials had both a regular and fire resistant version, so 6 different materials were used. Two sizes were made, Medium and Large; and they could be customized further by drawstrings at the waist, neck, and ends of the legs. A zipper, which would not be exposed to radiation, facilitated dressing and undressing. Aluminum foil was used to cover the remaining exposed areas of the pig such as feet and face.

On Encore, 55 pigs (weighing 26-43 lbs) were anesthetized in the field and placed in animal holders. Forty five of these were dressed in uniforms and placed at 8 stations (2110' – 7700' from GZ). The other 11 were naked and placed in cylindrical aluminum containers with portholes that were covered with different combinations of uniform fabrics. These 11 were placed at 3 of the same stations (3160' – 7700' from GZ).

On Grable, 56 pigs (weighing 25-53 lbs) were anesthetized. Forty-two were uniformed, put in animal holders, and placed at 8 stations (2170' – 6870'). Two of these pigs were partially protected by "Quartermaster Protective Cream". The remaining 11 of the heavier animals were placed in standard porthole cylinders, one of which had thermocouples placed in contact with its skin. These were placed at 5 of the same stations.

Photography, before, during, and after each shot was taken, including photos of each pig. Burns were evaluated as soon as possible after exposure, ~ 3-4 hrs, and also at 24 and 72 hrs; and biopsies were made. (Oesterling 1955: 3, 11-5)

<u>PLUMBBOB</u>

4.1 In Trimble, MI, about 1 October 1956, the breeding for 1,500 Hampshire-Landrace pigs began. Since pigs have a gestation period of about 4 months, they were about 3 months old on the first of May and weighed about 65 lbs. This was a reasonable weight for one person to handle. At this stage the pigs were shipped to the NTS. Pigs gain weight fast. After another month they weigh about 100 lbs, "a weight that makes handling in the field exceedingly difficult". (McDonnel 1961: 18)

The animal holding facility was on the south side of Frenchman Flat, between the Mercury highway and the Frenchman Flat access road. This area had: "accessibility to a plentiful water supply, excellent natural drainage, good access roads, and isolation from Camp Mercury".

Normally, late spring at the NTS is a time of moderate temperatures and humidity (< 10%). Unfortunately, 1957 did not have a normal spring. There were days with temperatures below 60° F, rain, fog, and even icing. If a large number of the pigs had caught cold, the program might have been curtailed or eliminated.

Ultimately, pigs were exposed in June to the Franklin (6/06), Wilson (6/18), and Priscilla (6/24) shots.

4.1.1 conducted surgical correction for injuries in the field.
4.1.2 obtained information about the combined injuries at supra-lethal to non-lethal ranges.

4.1.3 obtained the median lethal dose in 30 days following neutron-gamma exposure and was performed with CETG Project 39.7.
4.1.4 obtained information on missile injuries by constructing different types of enclosures and associated and missile producing structures.

On Franklin, 4.1.3 was conducted, but its low yield resulted in "insignificant exposures at the closest station". On Wilson, 4.1.3 was conducted with 264 pigs selected for uniformity of weight (83 $\pm$ 11 lbs). These were 47% castrated males and the rest female. They were exposed by twos in aluminum cylinders with ¼" wall thickness. Twelve pigs were exposed at each of the 22 dose levels. Four pigs were placed inside of a tank. A pilot study of glass-missile design was also conducted.

On Priscilla, 4.1.1, 4.1.2, and 4.1.4 were conducted.(ibid. 17-20). Three types of enclosures were constructed that were enclosed by blast-proof hog wire fencing. 1) 10'x20' with 1 foxhole with 1 pig.
2) Circular 35' radius, with battlefield debris generated, 1 foxhole with 1 pig.
3) Glass-missile - rectangular with glass wall on long side closest to GZ. Pigs were behind glass wall inside rectangular enclosures of 4 different sizes ranging from 23.5'x160' down to 13.5'x60'. Styrofoam collectors for the glass missiles were also located within the enclosures.

Enclosure Type	Distance from GZ (ft)	# Pigs	Enclosure Type	Distance from GZ (ft)	# Pigs
1	2630	20	3	4170	145
1	2730	20	3	5320	110
2	3000	40	3	6120	70
2	3930	40	1	7380	40
2	4150	40	1	9490	40
3	4430	145		**TOTAL =**	**710**

Rectangular enclosures were oriented with long side toward GZ.(McDonald 1961: 17-20, 24, 118, 147, 158)

8.1 On Priscilla, clothing and other items developed for the protection of the individual soldier in a nuclear environment were evaluated by exposing uniformed pigs. Also a skin simulant (molded from silica –powder–filled urea formaldehyde) was investigated as a substitute for animate skin studies. This simulant was an improvement of that used on UPSHOT-KNOTHOLE project 8.9. (Derksen 1960: 12) Five stations were used. At each of 3 of the stations, 4 pigs were dressed in 3 different Hot Weather uniforms, 2 of which were possible improvements to those tested on UPSHOT-KNOTHOLE. Three types of shielding materials were exposed as was face cream, and bare skin. The skin simulant was tested at 2 stations with 3 pigs each, for a total of 78 pigs exposed on Priscilla. NRDL calorimeters and radiometers were mounted at 2 stations; and at all 5 stations, duplicate exposure meters were used to bracket the energy levels.(Babers 1959: 5, 16-8)

<u>HARDTACK II</u>
4.2 During Hamilton and Humbolt, swine were used as a biological target, with immediate lethality as the principal objective. They were placed in 3 different types of foxholes, M-46

tanks, and M-59 armored personnel carriers at distances where lethal levels of radiation were expected without complete destruction. Also, an exposure array was designed to extend the data from PLUMBBOB regarding: median lethal dose in 30 days for swine and relative biological effectiveness of neutrons versus gammas. A median lethal dose in 30 days was also tested with mice.

Hamilton's low yield did not produce the objective of immediate lethality. Shot Humbolt's only objective was immediate lethality, and this "occurred only at ranges where the environment was destroyed by blast; the precise cause of death in the exposed swine could not be determined".(Moncrief 1961: 5)

Bb. Flash Blindness – Human

BUSTER

4.3 The first flash blindness project at NTS was conducted to determine the size, depth and duration of scotoma* occurring after the exposure of the human eye to the light from a nuclear detonation. (*Footnote: a partial loss of vision or blind spot in an otherwise normal vision field.) Human test subjects were trained to chart their scotoma on portable instruments. The participants orbited at an altitude of 15,000 feet in an Air Force C-54 approximately 9 miles from the Baker, Charlie, and Dog detonations. They observed the flash, then immediately began recording their visual acuity. Data recording continued until pretest acuity was regained. Some participants wore different types of goggles, others were unprotected, facing the detonation or facing away from it. Unfortunately, useful data were only obtained on the Charlie shot. Baker's low yield produced a low flash, and Dog had an inaccurate detonation position. (Byrnes 1952: vii, 1-3){4.3}

TUMBLER-SNAPPER

4.5 was conducted on Charlie and Dog to determine the effect of detonations at night upon the ability of military personnel to carry out vision tasks . Subjects were located about 10 miles from GZ in a light-tight trailer. A shutter arrangement was used to expose their eyes to the atomic flash. Some eyes were protected by a red filter, and some were unprotected.(Byrnes 1953: 3,11-2)

UPSHOT-KNOTHOLE

4.5 was similar to TUMBLER-SNAPPER 4.5. It had 12 military personnel as participants located in a trailer 7-14 miles from 5 shots. The second part of this project exposed 700 rabbits at distances of 2 to 42 ½ miles from 6 shots.(Byrnes 1955: 3-4)

PLUMBBOB

4.2 An electromechanical shutter was evaluated for effectivness in preventing or minimizing flashblindness. Two different stations were used for exposure to the flash: one was in a C-47 aircraft, and one was in a ground based trailer (on the ground):

	Distance to GZ (yards)	
Shot	**C-47 Aircraft**	**Ground Trailer**
Boltzman	21,200	17,600

Wilson	19,360	15,136
Priscilla	30,400	20,649
Hood	32,426	-
Diablo	-	18,304

Each station had arrangements for six human subjects and 4 or more rabbits that were placed in holders designed to minimize movement and insure proper positioning for exposure. It was concluded that the shutter did offer protection.(Gulley 1960: 4,11,14, 19)

HARDTACK II

4.3 Twenty five Army and Marine officers were separated into 3 groups that were located 5,700' from Hamilton GZ. At t=0, the 3 test groups were facing 90, 135 and 180 degrees away from GZ; and their eyes were open and unprotected by filters or goggles. Immediately after the shot, the participants read a Jaeger (vision) chart and noted the smallest line which could be read and the time at which this was determined.

A voice count of seconds was presented during the test procedure. At command, all turned to face a target array area, that was at about 230 to 260 degrees, where an oil tank and earth bunker were located. Men would move out from behind these constructions and different colored panels were exposed. The participants were asked if they could see these figures and colors. The test lasted about 60 seconds.(Verhuel 1960: 5, 24-6)

Bc. Humans in Military Equipment

JANGLE

6.3-2 Two medium tanks and one personnel carrier were used to assess the inhalation hazard to crews of armored vehicles, both during and following a detonation. The vehicles were exposed at 2000 feet downwind from Uncle. One tank was head-on to GZ with hatches open, one side-on with hatches closed, and the Personnel Carrier was head-on with the commander's and driver's hatches open. " -- at H+50 hours, after decontamination, the vehicles were operated with one tank leading with hatches open, and the other vehicles following with hatches closed." They proceeded "--up to and beyond the crater lip and return." Not surprisingly, the combined exposure of the vehicles during Uncle and through the contaminated area after the shot resulted in airborne activity that exceeded "by a large degree the maximum allowable concentrations established by the Department of Defense and the U. S. Atomic Energy commission for lifetime exposure." (Engquist 1952: ix)

PLUMBBOB

2.9 "Three F-89 all-weather interceptor aircraft participated in the successful delivery (Shot John) of a live air-to-air rocket –".The rocket was launched to detonate at 19,000' MSL. All crew members and aircraft were instumented to measure total neutron and gamma radiations. The radiation dose to the delivery crew was within acceptable limits, less than 5 rep neutron and 3 r gamma.(DASA 1957: 4)

Bd. Phantoms*

[*Footnote: "Phantom" is a term used in the field of radiology to describe a mass of approximately unit-density material which is used to simulate tissue." (which is usually considered to be live human tissue).(Chambers 1957: 11)]

BUSTER

4.1 determined the initial and the residual radiation dose up to approximately 2 hours after detonation at various depths in approximately unit-density material. Phantoms were constructed that were simply spheres made of Lucite with a central cavity of 5 cm in which detectors for radiation measurements were placed. Seven models were made with wall thicknesses surrounding the cavity of 0.6, 1.0, 1.6, 3, 5, 9, and 17.5 cm. The 7 models were suspended about 2' from the ground on an A-frame in a manner to minimize their shadowing each other. A-frames were placed at 4 distances from Charlie and Dog (1,100, 1,175, 1,275, and 1,425 yards) and at slightly greater distances on Easy (1,275, 1,425, 1,575, and 1,775 yards). Swine phantoms were also developed from a laminated masonite cylinder ¼" thick, 36 cm long, and 36 cm in diameter with the ends capped by a hemisphere of 18cm radius. Film packs were distributed throughout each swine phantom as detectors.(Chambers 1952a)

Essentially this same project was conducted again as JANGLE 2.4b (Chambers 1952a: 1-7) and as SNAPPER 4.4 (Chambers 1953).

UPSHOT-KNOTHOLE

2.2b Residual radiation fields had indicated the presence of an appreciable amount of low-energy gamma or high-energy beta radiation. The interaction of these two types of ionizing radiations was studied with phantoms to evaluate the possible effects of these radiations on man. Three types of phantoms instrumented with small ionization chambers (5mm in diameter and 20 mm long) were used: 1) Lucite spheres like those used in BUSTER 4.1; 2) A solid masonite sphere; and 3) a simulated man constructed of masonite. Participation was postshot on shot day of Badger, Encore, Simon and Grable and during Harry. (Chambers 1957: 9, 11, 13-5)

8.9 A skin simulant to be used in tests for determining burn severity behind irradiated clothing barriers was evaluated by exposures on Encore and Grable. Five stations , located between 5000' and 11,000' were instrumented to measure: the thermal radiation and its spectrum; the amount of thermal energy transferred through layers of clothing; and its effect on a plastic skin simulant. A correlation for the behavior of these simulants was sought between the nuclear environment and laboratory testing.(Monahan 1954: 3, 11-3; Ponton 1982a: 123)

TEAPOT

2.6 Phantoms resembling humans, 5'10" tall and weighing 160 lbs were made completely of laminated pressed wood. Miniature ionization chambers with tissue equivalent walls were imbedded within the phantoms to measure beta and gamma doses. Field activities were conducted post shot by first making survey measurements of beta and gamma doses in the fallout field near, but above, the ground surface. Then, 4 phantoms were generally used as a group and placed in prone and upright positions in the fallout field. They were later recovered and moved to another field location for more measurements. This was conducted

on 6 postshots. The upright "man" received doses differing by a factor of 8 between feet and head.(Imirie 1955: 3, 12, 16-6, 18,26)

PLUMBBOB

2.8 Laminated pressed wood sections of approximately unit density were used again used to construct phantoms; but these phantoms had a height of only 30", consisting of 20 wood sections 1½" thick. Their thickness (front to back) was about 10", shoulder width about 20", and weight 160 lbs. A wooden platform about 30" high supported each phantom. Imbedded about 1½" within each phantom was a standard depth-dose detector or a dose-rate standard. These two types of phantoms were deployed in the field post shot on Wilson, Priscilla, Hood, and Diablo between H + 45 min and H + 2 hrs; and they were recovered at about H+55 hrs. For comparison with the data from the phantoms, a masonite rack was assembled on which dosimeters were mounted and glass needles were imbedded at a depth of about 1½" inside the masonite. The rack was fielded on Wilson, Hood, and Diablo.(Dilanni 1959:14-6, 20)

C: BLAST – MEASUREMENTS

Ca. TOA (Time-Of-Arrival) and Velocity

JANGLE

1.2a-1 Blast switches and microphones were placed at stations located 90 to 910 m from Sugar GZ and 90 to 470 m from Uncle GZ. The TOAs obtained were used to obtain the shock velocity from which the peak airblast pressure was calculated.(Ponton 1982c:80; Jackson 1993: 8-9)

1.3a An attempt was made to measure TOA at 2 points with ranges of 800' and 1200' and altitudes of 400' and 600' (a 30° angle wrt GZ) using balloons, blast switches and pressure pickups. Although this project was beset by operational problems, some data is reported.(Rankowitz 1952: ix, 1-10)

TUMBLER-SNAPPER

1.4 Blast switches were mounted at 6 stations for Able, Baker, and Dog. When the air shock arrived at a blast switch, the switch closed and a signal was transmitted by cable to a blast hut which superimposed the signal on a timing signal and recorded it. Thus, the time at which the shock arrived at each switch and the distance between stations was known, so a shock velocity could be calculated. From this velocity, the peak pressure behind the shock was calculated. At each station, 2 poles were used: one pole had a switch placed at 50' above the surface; the other pole had a switch at 10' above the surface and one at the surface.(Clarke 1952: 11-21)

Cb. Smoke Rockets and Photography

JANGLE

1.3b Smoke rockets and photography were used to obtain the velocity* of the shock front.[*Footnote: At known locations behind GZ, a number of smoke rockets were set in a line perpendicular to the line of sight of a camera. Just before detonation, the smoke rockets were launched vertically. This resulted in a grid of vertical lines of white smoke from which light was reflected. When the shock front passed the smoke

trail, it refracted (disturbed, changed the direction of) the reflected light. This caused the smoke trail to appear broken at the shock front. Thus, the position of the shock was determined, and the timing of these position points was obtainable from the camera film. From position and time, a shock velocity was determined.] The shock velocity was used to calculate an "ideal" peak pressure (Pmax) behind the shock. Power failure caused erratic camera behavior on Sugar, but all went well on Uncle. (Moulton 1952: v,1-7)

1(9)-b The Naval Ordnance Laboratory used photographic techniques to measure cloud phenomena on Sugar and the base surge, column, jet, and smoke crown on Uncle. They then developed scaling laws based upon comparisons with the conventional high explosive results. (Young 1952: Abstract)

TUMBLER-SNAPPER

1.5 On TUMBLER-SNAPPER, smoke rocket photography measurements were taken on each of the 4 air drop tests. A second rocket line and camera were also employed on each of the 4 shots in an attempt to obtain measurements of particle motion of the smoke trails behind the shock front. However, this particle motion measurement was not successful due to insufficient space-time resolution of the instrumentation used. (Aronson 1952: 23-27,90-1)

TEAPOT

1.2 Prior to TEAPOT, there was uncertainty about whether the coalescence of the shock in free air and the shock reflected from the ground would first occur directly above the burst. After coalescence, the 2 shocks would proceed as one shock whose effect on aircraft would be less than the double shock situation. It was desired to obtain this information prior to MET for the development of the flight patterns for the important drone Project 5.1, see Section Aa. Other objectives were to determine Pmax versus distance on MET and HA and to study the effects of the surface and the heating of the air near the surface over natural and artificial surfaces.

Both direct shock photography and rocket-smoke-grid photography were used by NOL. Sixteen smoke rockets were used on Turk and 20 on Apple 1 and MET. The smoke grid was concentrated directly above the burst on these shots, and it was a grid pattern, not just vertical straight lines. The grid pattern was desired to obtain better space resolution for shock TOA, and it was achieved by firing the rockets at the two sides of GZ at angles of 60 and 70 degrees rather than vertically upward.

The standard smoke rockets could not reach the 36,620 altitude of the HA detonation. Therefore, horizontally flying aircraft flying at 400' differences in altitude released a smoke-producing agent (similar to skywriting techniques) to make the horizontal grid above the Ha detonation altitude. However, the grid trails were excessively spaced; and "ambient conditions at the altitude of the smoke grid were such that good condensation trails were not produced." (Moulton 1955: 5,15-6,19-20,23-7)

Cc. Gages - Over Pressure, Dynamic Pressure, Peak Pressure (Pmax), Particle Velocity, Sound Velocity

JANGLE

1.4 Pressure-time was measured by Sandia along the major blast line throughout the ranges where structural damage was to be investigated, from 500' to 4200' on Sugar, and 314' to 3100' on Uncle. Generally, two gages were used at each of the 8 instrument stations along the blast line to obtain duplicate measurements. In addition, to examine symmetry on Sugar, 5 Naval Ordanance Laboratory (NOL) "indenter" gauges were placed on the circumference of a circle having a radius of 1,700' from GZ. For Uncle, 4 NOL gauges were used on a circle of 1,200' radius. Wire and radio telemeter links were used to transmit data.(Howard 1952: 1-4)

TUMBLER-SNAPPER

1.2 At stations along the blast line, air pressure versus time measurements were made by SRI at the surface and at 10' and 50' above the surface from towers. (Salmon 1953a: 3, 26-28)

1.3 Pressure-time measurements were made by NOL with gages mounted flush on the ground as an independent check of other methods of instrumentation. The gages were laid out on a line that was about 10' to the right (when looking toward GZ) of the surface level gage line for Project 1.2. Most of the same ranges as Project 1.2 were used. Additional gages were placed on Able at 4,000' and on Baker, Charlie and Dog at 12,000'. On Charlie and Dog, gages that were being developed for measuring Pmax were also fielded near some of the pressure-time gages. (Aronson 1952: 23-4, 32-39)

1.13 David Taylor Model Basin (DTMB) used self-contained pressure gages (i.e., the recordings made were contained inside of the gage rather than sending them via an electrical signal to a central recording station). Such gages did not required costly cable and trenches. The objectives of this project were to provide airblast pressure data: (a) at ground locations where aircraft were being exposed (see 3.1 Section G); (b) at different azimuths to check for symmetry ; and (c) for comparison with other programs. Sixteen gages each were used on Baker, Charlie, and Dog. (Cook 1953: 3,11)

8.6 was conducted by University of California at Los Angeles on Able, Baker, Charlie, and Dog to determine the velocity of sound prior to the arrival of the shock wave at altitudes of 1 ½', 10', and 54' above ground level at distances of 0', 1500', 3000', 4500', and 600' from GZ. The travel time of acoustic signals between pairs of electroacoustic transducers placed at the 5 stations was measured. Instrumentation failures occurred on Able and Baker, but Charlie and Dog measurements were successful. (McLoughlin 1953: 3-6)

UPSHOT-KNOTHOLE

1.1a & 1.2 The Naval Ordinance Laboratory (NOL) made four types of measurements:

- About 50 pressure-time measurements were made on both Encore and Grable along 3 blast lines: the "Main Blast Line" (running for 15,000' due W from the IGZ, a "Smoke Line" (running for 5,000' at 20° N of E from IGZ); and a "Minefield Line" (located 500' E of IGZ and extending N for about 2500'). The Main Blast Line was used to acquire data for the height of

burst (HOB), pressure, distance curves being developed by the DoD as well as for use by other projects. The smoke line was positioned to examine the effect that a layer of smoke which was generated just prior to the shot would have on the blast wave. The Minefield provided data for the large minefield clearance project:

- For Encore and Grable, peak pressure gages along with new self-recording mechanical gages for pressure-time measurements were deployed on the main blast line and along another line running approximately 50° S of W.
- Peak pressures were obtained on 5 shots by the free air smoke rocket trail technique.
- High speed photography was used specifically to "follow the space-time history of the shock wave near the ground –". Nine high-speed cameras were used on Encore and Grable for this "first of its kind" photographic effort, which provided researchers with considerable insight. Incidentally, photography of smoke rocket trails complemented the approach.(Morris 1955)

1.1b SRI made both airblast and ground shock measurements:

- Pressure-time was measured in the air at different distances from GZ at and near the ground surface for 5 tests at different heights of burst (HOBs).* [*Footnote: Dixie 11 kt at 6020' above the surface; Encore 27 kt at 2433'; Climax 61 kt at 1334'; Grable 15 kt at 524'and Ruth 200 tons at 300'.] The spread in yields of was a factor of 300 and the spread in heights a factor of 20.
- The near-surface underground accelerations produced by air bursts were diagnosed with 175 air pressure gages and 27 acceleration gages. On Ruth and Dixie, there were 12 gage stations, on Encore 13, on Grable 17, and on Climax 14. (Swift 1955)

1.1c-1 SRI conducted pressure-time measurements along the blast lines on Annie and Simon. For Annie, a large concrete collimation wall was constructed for LASL's Projects 17.3 and 11; and there was concern that this wall had caused the blast wave on Annie to be asymmetrical. The same wall would be used during Simon, therefore, pressure-time gages were added to Simon for a Symmetry Study.

1.1c-2 Sandia conducted pressure-time measurements over hills and dales on Simon. See Section Cf for more details of this project.

1.1d Sandia fielded instrumentation for measuring dynamic pressure and preshock pressure. In addition, gage feasibility studies of new and modified gages were conducted for measurements of: temperature, wind velocity, sound, and air density. (Dixie and Encore)

1.5 is a summary of Projects **1.1c-1, 1.1c-2,** and **1.1d.** Information is also included about Sandia's ground motion measurements for projects 1.4a and 1.4b, which are described in Section E. This represented a major effort on a number of shots. A total of 273 data channels were recorded, 226 of which were "good", 32 "partial", and 15 "bad." The "partials" were usually due to failures of the towers that supported the gages. Most of the "bad" records were from failures of experimental gages.(Rollosson 1954:3,13-8, 21-5, 48-73, 81-87)

3.28 BRL, NOL, and SRI provided extensive instrumentation and measurement results for the other projects in Program 3,

3.28.1 BRL measured transient physical phenomena associated with blast loading of structures and of a variety of test items. On Encore and Grable, they provided 892 channels of instrumentation to obtain information on: air pressure, earth pressure, structural strain, displacement, acceleration, angular velocity, and panel-time-of-break* (*Footnote: this is the time at which a specific displacement occurs in the instrumented object. For instance, it may be the time when a break of 1/16 to 1/8 inch or a displacement of ½ inch occurs in a given structural panel).(Meszaros 1955: 3, 20)

3.28.2 NOL made pressure-time measurements for six of the structures projects (3.1, 3.1u, 3.7, 3.9, 3.13, and 3.19). A total of 128 pressure-time gages were installed for Encore and 105 for Grable.(Morris 1953: 15-17)

3.28.3 SRI fielded 78 gages at a radius of about 4900 ' on Encore and Grable. Fifty four of these were on structures of the 3.1 project, and 24 were apart from the structures to measure free-field conditions.(Swift 1954:13-17)

3.30 BRL tested 3 new prototype self-recording gages for pressure-time and peak pressure measurements. The gages were tested on the last four shots where they were used as backup gages in conjunction with measurements made on the other structures projects. The results were promising and estimated to cost less than 20% of electronic measurements. (Kingery 1954: 3)

8.12a NEL measured sound velocities in the air close to the ground by using an acoustic velocity meter. These meters were oriented such that they measured the sum total of wind velocity along the blast line and the acoustic velocity due to temperature. Also, 4 of the acoustic velocity meters were placed together to make a particle velocity meter that was used to measure: 1) both pre-shock and post-shock wind velocities in their 3 (mutually perpendicular) directions and 2) velocities due to temperature alone. These measurements were made on the Main Blast Line between 5000' and IGZ for Encore and Grable and along the Smoke Line out to 5000'. There were 8 acoustic velocity meters at 10' elevation, another 8 at 3 ½' elevation, and 2 particle velocity meters used along these lines. On Encore, 3 of the 8 velocity meters at 3½' were over a 28'x40'x3" mat of white fir boughs held in place on the ground by chicken wire. On Grable, this area was supplanted by sheets of cold rolled iron 1/16" thick painted with lamp black.(McLoughlin 1955a: 3, 12-7)

8.12b Three test panels 10'x10' were installed by DTMB at 1500' and 3000' from IGZ of Encore and Grable. They were inclined toward the IGZs (so they would receive more thermal energy). At the center of each panel, and at ground level, a pressure gage was mounted. The objective was to check on the possibility that pre-shock pressures might be generated by sudden exposure of a surface to intense thermal radiation. Black ceramic tile, black asphalt roofing paper, and an adobe made from Frenchman lakebed soil were used in the 3 thermal panels. (Benjamin 1955: 3,17-8)

<u>TEAPOT</u>

1.3 Sandia fielded 3 microbarographs and 3 millibarographs, and BRL fielded 10 self-recording very low pressure (VLP) self-recording pressure gages to measure Pmax of both

the free air and the wave reflected from the ground on shot HA. The range of possible pressure measurements was between 1.5×10^{-5} and 0.35 psi. The 3 millibarographs were located below the HA IGZ on a 34' pole, and on the ground at 12,000', and 24,000'. The microbarographs were all located on poles 60' high at ~34,000' from IGZ by the CP, ~82,000' by Frenchman Flat turnoff, and ~136,000' at Mercury. The BRL gages were located at 3 stations about 7 miles N, E, and W of IGZ on the ground and 2 on poles.(Reed 1955: 11, 15-21)

1.5 Using improved instrumentation on the MET shot, NEL made measurements of the velocity of sound from +20 msec until shock arrival. Measurements were made at heights of 1.5', 3', and 6'. Gages were placed at the 2000' range over water*, the 1000' and 2000' ranges over asphalt, and at the 1000' and 2000' ranges over desert soil. At the 2000' range over desert soil, 3 additional plots of dimensions 30'x20' (with the shorter dimension toward GZ) were developed. These plots consisted of: a concrete slab, broad leaf ivy, and fir boughs. They provided a low cost means of making comparisons of preshock air sound velocities over more and quite different materials.[*Footnote: A "lake", approximately 3000' long and 800' wide with a depth of 3" was constructed. The depth was limited to 3" because of the scarcity of water due to schedule delays and the large numbers of people at the site.](McLoughlin 1955b: 3, 9-11,23)

1.10 SRI measured static overpressure (side-on) and dynamic pressure versus time at different distances on MET with a trial run on Bee. There were 123 channels of instrumentation installed for MET and 24 for Bee. Instrumentation spanned the length of the water and asphalt surfaces with 10 stations. Instrumentation extended to about 4500' with 17 stations on the desert line. Gages were located at ground level, and on towers at 3', 10', and 40'. Recording for all of the blast lines' 123 channels of data was done in two shelters located at about 2200' and 3500' near the desert soil blast line. These two shelters were buried 3-4 feet under soil and constructed of reinforced concrete walls and ceiling between 10" and 2' thick. Ingress and egress was through a hole in the roof covered with sand bags. (Sachs 1957: 5, 17-20)

1.11 Sandia used two 3' towers, located side by side. One tower carried a particle velocity gage, a density gage, a force plate to measure head-on pressure, and a wind-direction gage to measure yaw* vs time. [*yaw and pitch are respectively, the horizontal and vertical angles of the shock afterflow.] The other tower carried a Snob** and a Greg** gage to measure dynamic air pressure and head-on pressure respectively. [**The Snob gage measured the dynamic pressure due to the air alone because it had a special probe that essentially filtered the dust. It was also capable of measuring the head-on pressure of just the air. The Greg gage measured the full head-on pressure of the dust laden air.] These towers were used on Turk for a trial run at one location and on MET at distances of 2,000' and 2,500' along each of the 3 blast lines. In addition, extensive pitch* measurements were made at different heights (generally, 3', 10', 25' and 40'). Distances from GZ were at the same, but not all of, the stations as used by project 1.10.(Banister 1956: 5,11,14-22,26-8)

1.12 A 3 component force gage for the measurement of transient aerodynamic drag loads was developed by NOL to obtain the loading on 3" and 10" diameter spheres. These gages were fielded as a trial run on Apple 1 and used on MET over the 3 surfaces. They were all located at 3' heights and at the same distances as SRI dynamic pressure gages (Project

1.10). For comparison purposes, some were fielded at locations similar to those used by BRL. Two gages were also fielded at 3500'.(Kornhauser 1955: 30-4)

1.13 NOL's beta densitometer determined total air density by measuring the attenuation of a beta beam (a stream of electrons) caused by the air and dust. They also determined the amount of dust and its particle size in the shock wave. The instruments were located 2500' and 3000' from GZ at 3' and 10' above the asphalt and desert soil surfaces. At each station, the detector units were housed within concrete bunkers streamlined for shock wave air flow, and the recording units were placed in a ground pit.(Gordon 1955: 12)

1.14a Aerodynamic drag forces exerted on 3" and 10" spheres subjected to airblast were measured by BRL along the blast lines.(Burden 1957: 4)

1.14b This large BRL project, with self-recording mechanical gages, was conducted on 12 shots. There were a total of 162 stations along the blast lines with a pressure-time gage at each of them. There were 77 dynamic pressure-time gages. The pressure-time gages were buried level with the ground surface. The dynamic pressure gages required mounts and were placed at 3' and 10' levels. A small drill rig dug the necessary holes. (Bryant 1955:Abstract, Chapter 2)

PLUMBBOB

Priscilla was the first test that placed emphasis on the high-pressure region, up to 1,000 psi for overpressure and up to 650 psi for dynamic pressure. This emphasis was due to the advent of thermonuclear devices and the increased hardening of military facilities.

1.1 BRL used 223 overpressure-time gages and 57 dynamic pressure-time gages during 14 shots. Nine shots were instrumented for precursor waveform information, and precursors were observed on 6 of the 9. Free-field blast measurements were made as required by projects that were testing equipment or structures during Priscilla. Measurements were also made in the low-pressure region (0.1 – 1 psi). They showed large variation in maximum pressure and indicated that temperature and wind velocity can substantially change a shock wave at such low pressures. (Bryant 1962: 5, 15)

1.2 prototype HARDTACK I instrumentation for airblast measurements was tested by NOL on Owens and Kepler:
1) Four parachute supported canisters containing self-recording mechanical pressure gages were deployed by means of their own rockets, and
2) One balloon at 200' supported the same type of pressure gage at a height of 25' above the surface. Three of the balloons for this project had been lost pre-shot, see Section Aa PLUMBBOB 5.2.(Hanlon 1957: 5, 9)

1.3 On Priscilla, SRI fielded 47 gages at surface level, 3' and 10', between about 76' and 4500' for a variety of pressure measurements with different types of gages. In addition, they fielded a line of 28 blast switches for TOA at surface level, another 23 at 3' above the surface, and 3 at 10'. The bulk of the instrumentation was located at less than 850' for measurements in the high pressure region.(Swift 1960b: 5, 28, 30)

HARDTACK II

1.7 A small crew of 4 BRL personnel conducted a variety of blast measurements, some of them with newly developed instruments, on 9 shots. The crew recovered the self recording gages and data on all of the tests except the tunnel test Evans which used telemetry. The shots and (the number of stations) were:
Eddy (7) New instruments were also evaluated; Mora (4); Quay (2); Lea (2); Hamilton (29) (also on Hamilton, jeeps, M48 tanks, and M59 armored personnel carriers that were placed between 20 and 90 meters in both the NW and SW directions were instrumented); Socorro (4); Rushmore (11); Evans (7) (also gages were in the Evans tunnel wall at various distances from GZ and telemetered data was received at monitoring stations); Humbolt (22). (Ponton 1982d: 88-9, 93-4,102, 108, 114, 138, 147-8, 160-1,168)

Cd. Parachute-Borne Canisters

JANGLE

1.3c Free-air peak pressure was to be measured on Sugar by dropping 8 parachute-borne canisters with pressure measuring instruments from 2 aircraft. Radar instrumentation was to position the aircraft for deployment of the canisters vertically above the detonation; instrumentation was to track the canister positions during their fall; and data from the gages within the canisters was to be telemetered. There was a large error in the deployed location of the canisters.(Haskell 1952: vii, 5, 14)

TUMBLER-SNAPPER

1.1 was similar to JANGLE 1.3c and conducted on Easy and How. Sixteen canisters were used which arrived closer to their planned locations. The two B-29 dropping aircraft were guided by 2 radar stations to their position and time for drop. In addition, 4 canisters were placed on the ground at various ranges from ground zero. (Haskell 1953: 3-17)

UPSHOT-KNOTHOLE

1.3 Air Force Cabridge Research Center (AFCRC) made pressure measurements of: 1) the free air shock; 2) the Mack shock near the ground; 3) the path of the triple point (where the free air shock and the reflected Mach shock coalesce); and 4) the coalesced shock. It was conducted on Dixie and Encore because their points of detonation were of sufficient height to give a good separation of direct and reflected shocks over a wide range of distances. Fourteen parachute-borne canisters were used on Dixie and 20 on Encore. Two B-29s did the delivery on each shot, and "complete data were received from all canisters in both tests." There was also an emphasis to obtain data in the low pressure region, below that covered by existing data (< 8 psi). (Haskell 1954: 3)

TEAPOT

1.1 Canister drops were made vy AFCRC on the low HOB tower tests Turk and Apple 1 to support Project 5.1, the drone-aircraft project on MET. Canisters were also dropped on HA to provide free-air overpressure-time data.(Haskell 1955: 3)

1.9 Smoke puffs were used by Sandia as a means of obtaining the position of the shock front as a function of time* at several locations on HA. As the shock front passes a smoke

puff, it distorts the puff. [*Footnote: By knowing the positions of the shock front at different times, particle velocity and the pressure in the air behind the shock front can be calculated.] An air dropped canister with parachute was chosen to launch the smoke puffs. On the axis of the canister, 6 grenade launchers were located. They each fired two M-15, "grenades in opposite directions. This produced a circle of 12 equally spaced smoke puffs around the canister, in a horizontal plane, at 30-degree intervals. It appeared that the smoke-puff canisters operated satisfactorily, but they were delivered about 900 feet above the detonation point. No significant conclusions could be drawn from the data.(Reed 1956: Abstract, 7, 9, 13)

Ce. Dust

TUMBLER-SANPPER

1.9 Dust samples were collected during the brief period of time, about 1 second, between detonation and the arrival of the shock wave. The Chemical Corps developed these samplers which were placed at 2 locations for Able and 3 locations for Baker, Charlie, and Dog. At each location, two dust-samplers were used: one at ground level and the other at 10'. The samplers were recovered as soon as possible post-shot and rushed to the Army Chemical Center. Results indicated: pre-shock dust was in concentrations of 10 to several 100 times background; pre-shock and background dust had the same particle size; and little variation in dust concentration was found from shot to shot.(Bouton 1952: 3, 13, 25-26, 30-1)

Cf. Hills and Dales

Sandia had conducted previous work regarding air blast in the presence of hills and dales on LASL's Weapon Development Programs. This work was:

- on BUSTER, there was instrumentation failure with inconclusive results and
- on TUMBLER-SNAPPER, 3 lines were instrumented for pressure-time, but the overpressures measured were low.

UPSHOT-KNOTHOLE

1.1c-2 One of the TUMBLER-SNAPPER lines, the ridge between Yucca Flat and Tippipah Springs, about 3 miles west of the Simon GZ, was instrumented by Sandia for pressures. Sixteen measurement stations were selected on the fore and lee slopes of the ridge and at outlying positions both in front of and behind the ridge. Pressure gages were fielded flush to the ground, powered by a generator; and data was recovered by personnel post shot. In addition, most of the stations also had prototype gages that were under development.(Merritt 1954: 9-10, 20)

PLUMBBOB

On Smoky, three significant projects (1.8a, 1.8b, and 1.8c) were involved in determining the effect of rolling terrain, steep slopes, and rough terrain on nuclear blast and how that modified blast would affect vehicles. Five Hill and Dale blast lines were used:

Line 1 – *Flat Terrain* used as the control line for comparison with other lines.

Line 2 – *Rolling Terrain* of small hills and dales.

Line 3 and Line 4 – two *Ridges* with approximately symmetrical front and back slopes.

Line 5 – *Rough, Mountainous Terrain*.

1.8a BRL instrumented all 5 of the Smoky Hill and Dale blast lines and a few scattered stations with self-recording and electronic gages. A prototype dynamic pressure gage was also tested. Self-recording gages were used for most overpressure and dynamic pressure measurements "because of their ruggedness, ease of installation, and overall ability to obtain reliable information under adverse conditions".(Bouton 1952) Four electronic gages measured overpressure, one measured dynamic pressure, and all arrival time measurements were electronic. Three dynamic pressure gages were mounted at 10' above the surface, the rest were at 3' as were all of the pitch and TOA gages. The gages fielded on each line and on jeeps placed in the field were:

Line	1	2	3	4	5	Jeeps	TOTAL
Overpressure	19	8	6	8	10	9	60
Dynamic Pressure	5	9	6	9	-	1	30
Pitch	3	-	4	-	-	-	7
TOA		11				8	19
					TOTAL		116

(Bryant 1957: 5, 15-6, 19-23, 42)

1.8b See Technical Area Ai for how the military vehicles responded to Smoky in the irregular terrain.

1.8c SRI placed gages along Lines 1 (5 stations) and 3 (6 stations). Line 1 was used as reference and had stations placed at the same ground ranges as on Line 3 so that direct comparisons could be made. SRI's gage placement had some similar ranges with BRL and at more remote ranges to provide backup and extended data. A surface level overpressure gage was installed at each of the 11 stations. Dynamic pressure was measured on gages mounted at 3' and 10' above the surface. A newly developed pitot tube type gage, developed to measure total pressure in the supersonic region, was also tested. (Bryant and Keefer 1957: includes work by Swift and Sachs1957: 117, 127-132, 135-7)

Cg. SMOKE SCREENS

UPSHOT-KNOTHOLE

8.4-1 Originally scheduled for Encore, high winds caused the cancellation of this project; but it was reorganized for Grable. A fog smoke screen that was generated from oil for Grable was created with 175 smoke pots, placed in 2 circles if 200' and 300' diameter that ringed the 2238' instrument station. The photographic records showed that the carbon smoke screen of Project 8.4-2 intercepted the thermal radiation incident upon this project's fog smoke screen. However, the photographs enabled an estimate of the reduction of thermal radiation resulting from each of the screens. It was estimated that the reduction of thermal radiation by the fog oil smoke screen was 85 to 90 % at the instrument station.(Engquist 1954a: 3, 61)

8.4-2 A black carbon smoke screen was generated for Grable by 451 Smoke Pots, Black, that were placed in 4 strips each 1000' wide and between about 300' to 500' in range. These strips were non-equally spaced at 4 ranges between 500' to 4600' from GZ in the area of the "minefield line" described in Project 1.1a/1.2. Analyses indicated that the blast wave was

markedly modified by the presence of the carbon smoke screen. The screen reduced the thermal effect, and Pmax and TOA were more nearly like that from a non-thermally heated reflecting surface.(Engquist 1954b: 3, 12-3)

D: AIRBLAST – INSTRUMENTATION DEVELOPMENT

Essentially all instrumentation development for airblast measurements was done as a continuing effort during the conduct of measurement projects. Folks would say, "We just bootlegged the development". Development tasks were generally not spelled out in the contract. What needed to be improved or invented simply was. The only two projects that were specifically directed at airblast instrumentation development activities in their title were on UPSHOT-KNOTHOLE and conducted by NOL.

UPSHOT-KNOTHOLE

1.1a-1 Naval Ordnance Laboratory (NOL) evaluated the Wiancko and Vibrotron gauges and developed new circuitry for nuclear testing. Transistor and tube systems were evaluated. The tests Encore and Grable were used (Jackson 1993: 11-2)

1.1a-2 NOL tested a modified indenter gage for peak pressure measurements and a new mechanical pressure-time self recording instrument on Encore, Harry, and Grable. These instruments were part of NOL's continuing program to develop "simple, inexpensive mechanical instruments for measuring blast pressure.(Jackson 1993: 11-2)

E: GROUND MOTION – MEASUREMENTS

This section addresses measurements made for ground motion which were generally made with gages emplaced underground or at the surface. Also included here are a few projects that examined in the laboratory those properties of geologic materials which influence ground motion.

JANGLE

1.1 was a large effort! A total of 158 measurements were made. Five were pressure measurements, the rest were of Horizontal (H), Vertical (V), and Transverse (T) accelerations in the ground. NOL used a new accelerometer and recording system for these measurements. Gages were installed between 200' and 3000' at 12 and 13 ranges from the Sugar and Uncle GZs respectively. At the 340', 642', 1213', and the 1890' ranges, gages were emplaced at 3 depths, 10', 20', and 30'. At the other ranges, a single depth of 10' was used. Nearly all of the horizontal and vertical accelerometers also had back up accelerometers installed. The transverse accelerometers were the fewest in number with only 4 installed on each shot at a depth of 10' in the aforementioned holes that went to 30'. Recorders and backup recorders, which recorded 100 signals from each shot, were mounted in trailers that were located 8,000' from GZ.(Morris 1952: xxi, 14-20)

1.2a-2 On Sugar and Uncle, BRL placed 17 accelerometers were placed in holes 10' deep at 12 stations. Most of the ranges for the station locations were the same as those used for Project 1.1. This project was to provide self-recording accelerometers as back-up measurements in the event of possible failure of the more complicated systems that used wire transmission of data. The more complicated systems, Projects 1.1 and 1(9)a, provided good data as did this project.(Andrews 1952: 11,17)

1.2b To obtain TOA of the ground shock, NOL used switches of two types, one a normally closed switch (that opened when ground shock arrived) and the other a normally open switch (that closed when ground shock arrived), were used. This redundancy was used because of the uncertainties associated with electrical circuits in a nuclear environment. The switches were placed in 31 holes, 6" in diameter and 17' deep, located from 5' to 333' on Uncle.

At 350' from Uncle GZ, a structure was built 12' under the earth's surface to contain and protect the electrical circuitry for the switches from ionization. Coaxial cable carried signals from the emplacement holes to this 350' structure, and coaxial cable carried the signals from the 350' structure to the 8,000' station where recording equipment was located for this and other projects. Good TOA data and calculated velocities were obtained.(Gannon 1952: 1-23)

1.5a An attempt was made by NOL on Sugar and Uncle to use high-speed cameras to measure horizontal and vertical transient ground displacement by photographing 3'x3' Fiducial markers that were installed on telephone poles. The poles were buried 10' to correspond with the depth of accelerometers buried at the same locations. The film was overexposed on Sugar, and the Fiducial markers were not visible on Uncle.(Morris 1952: 1-6)

1.5b DTMB obtained TOA of the first detectable earth motion by using a seismic detector that was connected to an electronic flash lamp unit. When the seismic detector first detected motion, it sent a signal to the flash lamp which would light; and the lamps were photographed over time at remote recording camera stations. Ten seismic detector-flash lamp stations were located on the main blast line of Uncle between 100' and 542'. The seismometer was buried at a 5' depth, a cable buried at about 1' ran to the flash unit which was located nearby in a cylindrical container. A mirror reflected the flash from the underground lamp to the remote surface cameras.(Cook 1952: 1-7)

1(9)-a Horizontal (H) and Vertical (V) accelerations, earth pressure, and air blast measurements were made by SRI at 20 ranges between 219' and 3080' on Uncle. Air blast gages were located at 6 ranges from 314' to 3080'. The remaining gages were all underground. Thirteen of the 20 ranges had H & V accelerometers that were placed on a radial line which ran 90° W of the major blast line at depths of 5'. The rest of the gages were placed as close to this line as possible. H & V accelerometers were also placed at 2 ranges with 17', 34', and 68' depths. Just H accelerometers were placed at 10' depth at 6 ranges. Fourteen pressures were measured at a depth of 10', 3 at 17', 3 at 34', and 2 at 68'. A buried concrete recording shelter (8'x11'x7'high with 2' thick walls and 2'of earth cover) was located at 2000'. It housed the recorders and associated control equipment and was entered through a hatch in the top. (Stanford Research Institute 1952: ix, 1-11)

3.28 Sandia fielded the instrumentation of all test structures on JANGLE. "The location and type of instruments and the expected magnitudes of loadings were specified by the structure research groups ---". Sandia procured and installed the necessary instruments, operated them during the test and reduced the field records to a form usable by the structure research groups --." (Lenander 1952: 1, 3-8)

3.29 The Naval CEREL analyzed soil in the vicinity of the structures tests in order to provide information that was necessary for assessing the response of structures to ground shock. (Jackson 1993: 8-12)

4.2 Around GZ, the earth's surface was measured before and after Sugar and Uncle. The post-shot crater lip and profiles are given. Soil characteristics were measured. (Vaile 1952)

<u>TUMBLER-SNAPPER</u>

1.6 was conducted BY brl as backup to project 1.7 On Baker, Charlie, and Dog. At every other station along the main blast line, two self recording accelerometers were mounted perpendicular to each other on a steel plate (18"x12") and placed at the bottom of a 5' deep cased hole 3' in diameter. This steel plate was then bolted to another similar steel plate that was in turn bolted to the top of an 18" concrete cube grouted into the undisturbed earth. The cased hole was filled with sandbags and sand. (Recovery of the gages and data of course entailed the reverse process.) On Able, a trench rather than a cased hole had been dug and backfilled at each station. (Fischer 1953: 3, 10,16-7)

1.7 BRL made ground acceleration-time measurements at three depths:1', 5', and 50'. For Able, the principal measurements were of the vertical acceleration at the 5 foot depth at 11 stations, 200 through 210. Vertical accelerations also were measured at Stations 203 and 210 on all four shots at the 50' depth. A few horizontal radial and horizontal transverse accelerometers were also located at Stations 203 and 210. Two of these radial and transverse gages were replaced on Baker and Charlie by vertical ones located at a depth of 1'. With the gages already at the 5' depth, this provided some data on the effect of depth.(Salmon 1953b: 3, 24)

<u>UPSHOT-KNOTHOLE</u>

Sandia Laboratory fielded:

1.4a instrumentation for earth stress on Annie, Encore, and Grable.

1.4b strain gages on Annie, Encore, and Grable.
(Parret 1957)

<u>TEAPOT</u>

1.6 The crater formed by ESS was measured by ERDL and BRL as were the pre- and post-shot locations of sand columns. Before the detonation, slanted columns of colored sand were placed in the ground along a line running through surface zero. The pre-shot location of these columns was carefully surveyed. In October 1955, residual contamination from the detonation had decreased to an acceptable level, and excavation of the ESS crater began. The columns of colored sand (which were usually located beyond the region where material

was ejected to produce the crater) were uncovered, and their positions were surveyed and compared to their pre-shot positions. The displacements that occurred along the columns were thus determined. [Ponton1981b: 86] Characteristics of the crater (such as lip height and slope of the crater walls at different azimuths) could be related to the final displacements. This sand column technique was be used on many subsequent cratering events. The ESS crater had the following average true crater dimensions: Volume, 2.62 x 10^6 ft^3; Diameter 284.8 ft; and Depth 89.6 ft. (Schuster 2001: 29,30)

1.7 Twenty-eight ground motion gages were emplaced by SRI between 200' and 600' from ESS GZ on a blast line running N 38° W. They were mostly at a depth of 10': 9 acceleration; 6 horizontal earth stress; and 9 strain. There were also 4 airblast pressure gages at the surface.

Instrumentation was provided for the structures constructed for projects 3.1.1 and 3.3.2 Also, 2 horizontal stress gages and 46 measurements of dynamic displacement were made at 300' from GZ. In addition, 40 monuments to obtain total displacement were installed in groups of 10 each on 4 mutually perpendicular lines, at ranges from 180 to 500 feet. Their pre and post shot locations were determined by survey. (Sachs 1955: 13-4, 40-4)

3.10 BRL measured the loading and response of test structures for projects 3.2, 3.4, and 3.7: pressure, accelerations, displacements, and strains. Twelve test structures and 6 instrument shelters were instrumented.(Lorrain 1958)

PLUMBBOB

1.4 On Priscilla, SRI made underground measurements of acceleration, stress, and strain wrt time and distance with emphasis on the high pressure region. At 750' and 1050', 21 gages were placed at depths of 1, 5, 10, 20, 30, and 50 feet. Six of the gages were vertical acceleration, 2 horizontal acceleration, 6 vertical stress, 2 horizontal stress, and 5 vertical strain. At ranges of 450', 550', 650', 750', 850', and 1350', 2 vertical acceleration at 5' and 10' depths and 2 vertical stress measurements also at 5'and 10' depths were made.

To obtain seismic propagation velocities and their variation with depth, seismic studies were conducted. Small charges were set off at various depths in two holes that had been drilled to 200' near the Priscilla blast line. To obtain vertical compressional wave velocities, geophones were placed near the top of the hole and at 50' and 100' from the hole. Ten foot holes with geophones were also used to determine horizontal velocities. (Swift 1960a: 5, 13, 30-3)

1.5 Sandia conducted ground motion measurements on Priscilla with an emphasis on pressure ranges greater than 50 psi and depths greater than previously studied. They fielded (P = Overpressure; V = Vertical Acceleration; R = Radial Acceleration; D = Displacement) gages were at 5 range locations:

Range (ft) →	75	650	650	850	850	1050	1050	1050	1350
Predicted Over-pressure (psi) →	Not Speci-fied	400	400	200	200	100	100	100	50
Depth (ft)									
0	-	P,V,R	-	P.V.R	V*	P,V,R	-	V*	P,V,R
10	-	V,D	V	V,R,D	-	V,D	V	-	V,R,D
30	V	V,R,D	-	V.R.D	-	V,R,D	-	-	V,D
60	V	V,R,D	-	V.R.D	-	V,R,D	-	-	V,R,D
100	-	V,R,D	-	V.R.D	V**	V,R,D	-	V**	V,R,D
200	-	V,D	-	D	-	D	-	-	D

* Actual depth, 1 foot.
** Actual depth, 99 feet

The 12" diameter instrument holes were not lined. The instrument rack consisted of 5 vertical steel bars arranged 120° apart and wrapped at a 12" diameter with spiral steel cabling. The spiral steel cabling used a 3" pitch for the total length of the instrument rack. Accelerometers were placed in steel boxes and welded to the rack at the appropriate levels. Signal cables were run through a ¾" conduit within the steel cage and through flexible conduit from the rack to the cable trench adjacent to the hole. The holes were backfilled with concrete of about 3,000 psi strength.

To measure permanent displacement, underground concrete columns were also fielded. One set was 2' in diameter and 3' deep. The other was 8' deep and about 7" in diameter. They were simply surveyed pre and post shot.(Perret 1960: 5, 11, 16, 22-4)

1.7 The University of Illinois studied the loading produced on buried structures by pressures from the Priscilla airblast, with emphasis on pressures of 100 psi. Previous studies had lacked scope. This was due primarily to the cost of building underground structures. With its 68 drums, this project certainly provided scope. The test matrix represented a classic parameter study.

The drums were rigid steel cylinders, 2' in length and 2' in diameter with ends made of flexible aluminum diaphragms. Different diaphragm thicknesses (0.04". 0.08", 0.125", 0.25", and 0.50") were used to provide variations in structural flexibility. The permanent deformations of a diaphragm would provide a measure of the average peak pressure acting on it. Thirty eight drums were placed at 100 psi, 15 at 200 psi, and 15 at 50 psi. The depths for the drums were 0, 1', 2', 5', 10', and 20'. At most depths all diaphragm thicknesses were used, and placement occurred at the 3 pressure ranges for each depth. The drums were placed in backfill of the natural soil from Frenchman Flat. The backfill was then compacted so that its modulus of deformation would match as closely as possible that of the undisturbed soil.

Static strain gages mounted on each diaphragm gave an indication of the condition of the diaphragms after completion of the backfill and before the application of the dynamic load. They also gave the condition of the diaphragms after the test. To determine the dynamic deformation of the diaphragms, SRI strain gages were also used on the diaphragms. In addition, 3 stress gages were used to provide data for comparison with Project 1.4 and nine BRL self-recording pressure-versus-time gages that were located at 3 ranges.(Bultmann 1960a: 5, 11,12, 15-7, 19-20, 24-5)

3.7 BRL provided instrumentation to measure air blast and ground shock loading and the response of structures for DoD programs 3.1, 3.2, 3.3, and 3.6 and for FCDA's projects 30.1, 30.2, 30.3, 31.4, and 31.5. The specific types of instrumentation provided are identified in reports of those projects. Their activities included providing both self-recording gages and electronic gages for which they also supplied transducers, calibration, gage mounts, recording, and data presentation. A total of 330 recording channels were used of which 161 were magnetic, 127 were time-dependent self recording, and 42 were peak indicating.(Meszaros 1960b: 5, 13, 23)

3.8 Waterways Experiment Station obtained data on the character and some physical properties of the natural soil to a depth of 200' in Frenchman Flat. They did the same for remolded soil used as backfill. This project which represents the first formal project of its kind at NTS indicates the increased importance being placed on the geologic media. It provided soil data to projects 1.4, 1.5, 1.7, 3.1, 3.2, 3.3, 3.5, 3.6 and 30.1, and 6.1. Each project specified what data it wanted. A variety of <u>sampling</u> techniques were used, among them were: sack samples (simply placing loose material excavated from the site into a burlap bag); an assortment of drilling and coring techniques; and samples hand cut from the walls of a excavation. <u>Field classification</u> of the samples was based on the Corps of Engineers soil-classification system and consisted of: visual description and/or mechanical analysis and the determination of liquid and plastic limits, field density, water content. <u>Laboratory Tests</u> entailed sending samples to the WES laboratory for classification tests and possibly: compaction and consolidation tests, shear strength, stress strain characteristics, and compressive modulus, and sound velocities.(Goode 1959: 13,15,18-9, 23, 29-32)

<u>F: GROUND MOTION – DEVELOPMENT OF UNCONVENTIONAL INSTRUMENTATION</u>

As for airblast, the development of ground motion instrumentation occurred essentially each time ground motion measurements were made. These 3 unconventional ground motion projects were only conducted once, but they illustrate AFSWP's willingness to explore a variety of avenues to attain its goals.

<u>JANGLE</u>

1.6 On Sugar and Uncle, shear shafts were emplaced in the ground; and their permanent displacements were measured post-shot. This project was conducted by the Ohio River Division Laboratory (ORD) of the Office , Chief of Engineers. Each shaft consisted of 9 lengths of steel pipe, each 5' long and 6" inside diameter. The 5 segments were joined together with a metal sleeve tacked-welded to the pipes for a total length of 45'. The shafts

were placed in drilled holes, and sand was packed around the pipes to assure full contact with the ground. Fifteen such shafts were fielded on each of the tests along 3 lines running W, S, and 15°S of E. The fielding of these shafts represented a considerable field effort. The only permanent displacements were on the 2 closest-in shafts along Uncle's main blast line at ranges of 250' and 312.5' ; and the displacement at 312.5' (0.74') was larger than at 250' (0.66').(ORD, OCE 1952: vii, 1-5, 10, 20)

1.7 Shock pins had been used in Japan for earthquake research as early as 1899.(Hansen 1952a: 2) MIT and OCE explored the usefulness of such shock pins for this project. "The magnitude of acceleration required to overturn a given size pin is dependent not only upon the diameter/height ratio of the pin, but also upon the actual height of the pin, and the frequency of the ground motion."(ibid., 6) Steel shock pins of 3" and12" heights with diameters varying from 3/16" to 3" were fabricated. (ibid., 15) Groups of 12 pins were placed in racks that allowed the pins to overturn when the base plate on which the rack was placed was accelerated. The racks allowed some pins to overturn during the positive phase of the acceleration and some to overturn during the negative phase of acceleration.(ibid 21) At 15 locations on each shot, a base plate (that was designed to move with the surrounding soil (ibid., 28)) and rack was placed about 2' underground in a pipe with a lid that was covered with soil. Results from these pins were compared with accelerometer gauge results providing the conclusion: "Shock pins may be used to provide a very rough value of the horizontal acceleration ---- . This may only be done, however, when some approximate indications as to the magnitude and frequency of the acceleration and the distances to the --- pins are known."(ibid.50)

PLUMBBOB

1.9 For many design purposes, it is desirable to specify ground motions in terms of shock spectra. A device was developed and tested by ARDC and Ramo Woolridge Corp. for the direct measurement of shock spectra. Each gage consisted of 10 masses attached to a cantilever spring and mounted on a vertical plate. On arrival of the shock wave, the movement of each mass was obtained on a record plate which was marked by the movement of a stylus attached to each mass. The length of a mark was a measurement of displacement at the natural frequency of each spring-mass combination. The frequency spectra of the shock could thus be obtained. The devices with record plates were recovered post shot for analysis after 5 tests: Stokes (4 gages, @ surface); Smoky (2 gages, inside shelter and 3 @ surface); Galileo (3 @ surface); Whitney 2 @ surface);and Charleston (7 @ surface).(Halsey 1959: 4, 11-5)

G: STRUCTURES

BUSTER

In the spring 1951, the Federal Civil Defense Agency (FCDA) was the organization responsible for civil defense (CD) in the US; and it sent observers to GREENHOUSE in the Pacific. Civil Defense organizations in the United States from WWII to 1951 had a torturous history. The frequent changes that occurred in the organization and funding of civil defense work are in stark contrast to the relative stability of the AEC and DoD over the same period.

On BUSTER, the FCDA had a limited project to test family shelters with the DoD; and, in collaboration with the AEC, participated in another project for a larger communal shelter. The DoD conducted these two projects as their nuclear weapons effects projects 9.1a and 9.1b.

By UPSHOT-KNOTHOLE, the FCDA had its own test group at NTS that conducted a large sub-operation titled DOORSTEP on shot Annie. However, throughout the years of atmospheric testing, AFSWP assisted and collaborated with the FCDA. Today, the FCDA documents by both FCDA and their contractors that report these projects can be found in the DoD Defense Threat Reduction Agency's (DTRA) archives at the Defense Threat Reduction Information Analysis Center (DTRIAC) located on Kirtland AFB, Albuquerque, NM.

9.1a was conducted to determine the effects of atomic explosions on small shelters that could be built by the average householder with available materials. Data developed by Lehigh University Institute of Research served as a guide to selecting four types of shelters.

A total of 29 shelter structures of four types were constructed:
Type A - 18 Covered Trenches
Type B - 5 Metal arches
Type C - 4 Wood-arches
Type D - 2 Basement Lean-tos.

Several configurations were tested. The Type A covered-trench shelters were prefabricated of wood and were small enough to be moved by truck and lowered into its site by an A-frame. It appears that a workman could neither fully stand nor fully lie down in one of these structures. The Type B, C, and D shelters were constructed in situ. The sites were located 25 feet apart along an arc 1200 feet from the Station 3 target point. (Flynn 1952:5-20)

9.1b was the study of nuclear explosion effects on a 48-person communal shelter that had been designed by the AEC in liaison with the FCDA. Such shelters were intended for installation at what were considered to be the AEC's prime targets, like Hanford. The communal shelter was built 800 feet from Station 3, which was the air-drop target for shots Baker, Charlie, and Dog. The shelter was a horizontal cylinder, 48 feet long (note, only 1 ft per person) with a 7.5-foot inside diameter, perpendicular to the radial from GZ. Half was pre-cast concrete pipe, and the other half was iron pipe. Two ramps were poured-in-place at the ends of the pipe. Three feet and 3 2/3 feet of earth were placed over the concrete and metal sections of pipe respectively. (Corsbie 1952, 1, 3, 8; George 1979)

<u>JANGLE</u>
Program 3, Blast Effects On Structures, consisted of five projects on Uncle that were conducted by the Navy, Army, and Air Force. The 5 projects were: 3.1 Navy (Hazzard 1953:iii, 6, 118); 3.2 Army (Hansen 1952b: 4-30); 3.3 Air Force (Armour 1952: 7); 3.28 Sandia's instrumentation of the structures; and 3.29 Navy's soil mechanics tests (see Section E for 3.28 and 3.29).

3.1, 3.2, 3.3 The construction in support of these 3 projects was staggering! They consisted of 65 major structures or structural elements, categorized by 26 different designs. Some of the structures were fairly simple structures, like large boxes, probably designed to simplify the analyses of loads. Most of them were very representative of actual facilities.(overview by George 1979:128-135; for 3.1 Hazzard 1953; for 3.2 Hansen 1952b; for 3.3 Armour Research Foundation 1952))

Unfortunately, the structures were essentially untouched by Uncle "because the coupling of energy into ground shock had been grossly overestimated." [Lewis 1997: 18]
These projects represented a very significant effort by the armed services.

<u>TUMBLER-SNAPPER</u>
3.1 Three impressive revetments were constructed for this project: a G-Type, also referred to as a "Russian Revetment"*; a wall revetment; and a pit revetment. Schraut (1953: 42) states:"Initial investigations indicated that the G-Type revetment would be the type to investigate according to information then available from the Directorate of Intelligence, Target Analysis Branch." DoD projects were generally focused on offense – how to destroy enemy targets; and the Civil Defense projects were of course more focused on defense – how to protect people and assets.

The structures were built primarily with the local soil. Timber shoring was employed for the near vertical walls. The G-type revetment had the soil surfaces stabilized. The wall and pit soil surfaces were not stabilized. Four aircraft were placed behind these 3 revetments (2 in G-Type, 1 behind the wall, and 1 in the pit) for each shot. (ibid: 42, 47, 52) A total of 28 aircraft were subjected to the Baker, Charlie, and Dog detonations both behind the revetments and in the open. The majority of the 28 test aircraft were "obsolete and did not include any foreign types": 16 F-47s; 2 F-86s; 1 F-90; 7 B-17s; 1 B-29; and 1 B-45. The ranges at which the aircraft were placed spanned the range from no damage to complete damage. Each detonation had a somewhat different arrangement of aircraft type, location, and orientation with respect to GZ; however, the entire program was keyed to the 31 kt Charlie. (Schraut 1953: 3-4, 39-41)

See also Section Cc, TUMBLER-SNAPPER 1.13.

Airblast pressure-time was measured on, or near, parked aircraft on Project 3.1. The total thermal energy received per unit of area was measured as was the angle between the horizontal and the direction of flow of the advancing air mass behind the shock front. Total gamma radiation was measured using film badges. Strain measurements were made in a few wings and one tail. Variations of skin temperature with time and the acceleration of an aircraft's center of gravity were also measured, and there was photographic coverage.(Schraut 1953: 44-45, 321)

<u>UPSHOT-KNOTHOLE</u>
3.1 was a classic experimental parameter-study to study conducted by AMC and Armour Research Foundation (ARF) to examine various parameters of a structure (e.g. height, width, etc.) and the airblast (peak pressure, wave form, etc.) interact. It is described here in some

detail because of its pragmatic approach that is representative of the science done during atmospheric testing and because it represented a considerable construction project.

Sixteen structures with opposite walls the same size were constructed of reinforced concrete and filled with soil to study different parameters. One additional structure, 3.1q, had only 3 rectangular walls. The structures were considered to be rigid and were designed not to move during the blast loading. The structures, their Height, the ratio of Height:Width:Length (H:W:L), the parameter each was intended to address, and the number of instruments were:

Structure	**Height (ft)**	**H:W:L**	**Parameter**	**# Instruments**
3.1a	6	1:2:1	All of the parameters	27
3.1b	6	1:6:1	Width	16
3.1c	6	1:1:1	Width	10
3.1d	6	1:2:1/6	Length, Shielding	8
3.1e	18	1:2:1	Size	6
3.1f	12	1:2:1	Size	5
3.1g	6	1:2:1	Orientation 22 1/2°	25
3.1h	6	1:2:1	Orientation 45°	25
3.1i	6	1:2:3	Length	6
3.1l	6	1:2:1/6	Shielding	5
3.1m	6	1:2:1/6	Shielding	6
3.1n	6	1:2:1/6	Shielding	2
3.1o	6	1:2:1	Elevation	7
3.1p	6	1:2:1	Elevation	7
3.1q	4.5	1:2:2	Three walls	11
3.1s	6	1:2:1	Peak Pressure	24
3.1t	6	1:2:1	Peak Pressure, Corner Effects	24

Fifteen of the structures were located 80' to 200' apart along 2000' of a circular arc at a distance of 4900' from the IGZ of Encore and Grable. The other 2 structures, 3.1s and 3.1t, were at 1150 and 200 ft from IGZ. Except for 3.1g and 3.1h, they were all oriented such that the airblast would be perpendicular to the width side. Three structures, 3.1l, 3.1m, and 3.1n, consisted of a pair of thin (1 foot) walls that were separated by varying shielding distances. Instrumentation was fairly extensive: "Some of the surfaces had as many as 8-10 gages. However, many of the surfaces had only one gage", and others none. (Gallagher 1955: 24, 27, 31)

3.1u NOL used results from Project 3.1 Structure 3.1t to determine the shock diffraction pattern in the vicinity of a structure and the distance necessary for the diffracted shock to recover and become identical with the free-field shock wave.(Morris 1959: 9)

3.3 AMC and ARF used 5 cylinders to examine the effects of: shock strength, size of cylinder, its distance from the ground, and three-dimensional effects. Four cylinders were 6' in diameter and 20' long, fabricated out of ½" steel plate, and the 5th was 1 ½ ' in diameter and 5' long (1/4 size). They were closed at both ends and securely supported, to represent rigid bodies. One of the 6' cylinders and the 1 ½ ' were placed horizontally at 4900' from the

IGZ of Encore and Grable at 36" and 9" respectively above the ground. The other three were placed at 6375' at 4", 18", and 36"above ground. All were oriented with their longitudinal axes normal to the shock.(Sevin 1955c: 3,17,21,26)

3.4 Representative components of bridge structures were exposed at 2000' from Encore and Grable to determine their blast loading. These nuclear loads were compared with the results of steady-state wind-tunnel tests conducted on scaled models.(Sevin 1955d: 3)

3.5 Ten wall and seven roof panels (representing typical construction practice e.g. masonry, reinforced concrete, metal, and wood siding, etc.) were positioned in three overpressure regions on Encore. Pressure gages, motion picture cameras, and a strain gage system which measured the blast forces transmitted by the panel to its supporting structure were used.(Sevin 1955a: 3,33)

3.6 was the only project conducted during atmospheric testing for railroads. Sixteen items of standard railroad rolling stock were exposed. The items were placed on small sections of constructed rail bed with ties and exposed between 1520 and 6600 feet from the actual GZ on Grable:
1 welded tank car (empty)
1 riveted tank car (empty)
5 wooden boxcars (empty)
5 wooden boxcars (loaded)
1 steel boxcar (empty)
1 45-ton diesel electric locomotive, and
2 plywood boxcars (empty, type used in Army overseas operations).
Instrumentation consisted of motion picture cameras, pressure gages, and accelerometer gages. (Sevin 1955b:)

3.7 Six vents (for air intake or ventilation) and two entrance ways of simple designs were tested on an underground structure (about 41'x14'x8' high) buried about 2'. This structure was constructed 963' from Encore GZ and 765' from Grable GZ. Test results were compared with shock tube tests.(Sinnamon 1955: 3, 20, 26)

3.8 Three small underground structures, with 1', 4', and 8' of over-cover, were constructed 900 feet from the Encore and Grable IGZ. Ceiling beam strips of 8' span and different flexibilities were used in the structures. Instrumentation was fairly extensive: pressures, strains, deflections, accelerations, permanent strains, and permanent deflections.(Newmark 1954:3, 26-29,33)

3.9 Part 1 Fifty simplified structures were used to represent 12 command posts, 19 machine gun emplacements, and 19 two-man foxholes. These structures had different strengths and materials and were located in groups of 16 or 17 at 500', 1500', and 4000' from the Encore and Grable IGZ. Peak pressure was measured inside and outside of one of each type of structure. The main diagnostic was pre- and post-shot photography and visual inspection.

Part 2 made peak pressure measurements in 8 additional structures: 4 uncovered foxholes 2'x4'x6'; 1 partially covered foxhole, 1 command post, 1 machine gun emplacement, and 1 covered foxhole which were located at about 4000' and 7000'.
Part 3 An additional 22 two-man foxholes (at 4000', 6000', and 8000') were instrumented with passive indicators, calorimeters and film badges. These foxholes were arrayed in different orientations with respect to GZ. (Fowler 1954: 3, 33, 36-40, 62,92, 124-5)

3.11-3.16 These 5 Navy projects generally represented somewhat modest construction and had some instrumentation, but it relied heavily on other instrument projects: (Longmire 1955: whole text)

Structure	Approx Range to actual GZ on both Encore & Grable (ft)	Instrumentation
Project 3.11 – Steel Warehouses **3.11a** Reinforced 40'x100' **3.11b** Plain 40'x100'	 12,000 20,000	Program 1
Project 3.12 – Protective Brick Construction Panels **3.12a** Typical 1 story brick building with timber roof 44'x21'4"x11'6"high with 1'6" walls, completely covered with panels on roof and sides. **3.12b** Precast panels (20'x10' & 20'x5') tested on foundations **3.12c** Precast panels (20'x10' & 20'x5') tested on foundations	4,900 7,600 9,300	Crack analysis and permanent deflections
Project 3.13 – Pre-cast Shelters and Torque-Tube Panel **3.13a** Precast gabled personnel shelter (22'x48') with tunnel entrance & 3' earth cover on Encore. Cover removed for Grable **3.13b** Precast gabled personnel shelter with blast wall and no cover (Encore) **3.13c** Torque-tube panel (designed as a torsional pendulum which provides time delay as well as shock absorbing qualities and load reduction in the transfer of load to the frames.)	2,700 Encore 2,300 Grable 4,900 2,250	Pressure-Time & Deflection
3.14 Pre-cast Warehouse (40'x120')	6,500	Deflections
3.15 Corrugated Steel Shelter-Cover 25'x48'steel arch personnel shelter for comparison with 3.13a	2,700	Deflection, strain, pressure

3.16 Windows and Glazing 3 identical wood structures with windows on all outside walls and skylight in roof tested: window designs, glazing, screens, inside curtains, outside shields.	 7,600 12,500 20,000	Photographs

3.22 Two 100' Bailey bridge spans were erected: one was exposed to Encore, and both to Grable. Also, two single bay sections of a Bailey, (in major use by the Army at the time) and of a T6 (a promising new fixed bridge) were used. The Bailey panel is 10' long and approximately 5' high, and panels can be pinned end to end to provide the desired length, bolted side-by-side, or one above the other to obtain the desired capacity. The T6 has the same components as the Bailey, but is 15' long and has a larger carrying capacity. On each shot, the bridge elements were exposed at 3 locations where peak overpressures were between about 3 and 19 psi. Acceleration was measured and motion pictures were obtained.(Moore 1954: 3, 24-5, 31)

3.29 "The Motels", which can be visited today at the site, were four long, low, narrow structures that were constructed for this project (which was fielded by the FCDA). But, this was not a building test. It was a test of partitions and curtain walls under a roof. The motels were 303' 10" in length, 11' 2" high and 16' deep, and open at both ends of the depth (the long length was represented by only the roof, no side walls).The length of each structure was divided into 18 cells. Two motels were located about 6,625' from GZ, and two were located at about 4,400'. Curtain walls with and without openings, of different sizes and were made of various materials (brick, cinder block, reinforced concrete, corrugated steel etc.) and construction techniques. Interior partitions of cinder block, wood, steel, and plaster were exposed. Motion pictures were the main diagnostic.(Ponton 1982a: 104-5; Taylor 1956: 5, 19,28)

<u>TEAPOT</u>

3.2 To determine the effects of ideal and nonideal wave forms on a structure, four identical structures, 3'x3'x6' high were constructed monolithically along with the 12'x12'x3' thick reinforced-concrete slab on which each structure sat. The top of the slab was flush with the ground surface, and the structure was designed to resist any permanent defection. These structures were identically located at 2000' from MET GZ and were identically instrumented with pressure gages. Three of the 4 structures were located on the: asphalt, water, desert lines that were constructed for MET. The fourth was also on the desert line but the soil 200' in front of it and 50' on each side was loosened*. [*Footnote: "Frenchman Flat soil has 2 conditions: "(1) a very loosened, fine powdery state --- readily blown around --- and (2) a hard, compacted state --- quite resistant to blowing. An attempt was made to reproduce these two states in front of the two structures". Loosening was done by plowing and harrowing the soil a few days before the shot.] Two nearby structures from UPSHOT-KNOTHOLE 3.2 were also instrumented with pressure gages.(Schmidt 1959: 5, 17-21)

3.3.1 To examine the relationship between the flexibility of a structure and the ground shock loads experienced, 15 flexible "configurations" of various designs were constructed of steel and concrete and placed 14' apart underground at a DOB of 15' along an arc 300' from ESS GZ. This project sought the relationship between the flexibility of a structure and the ground

shock loads it experienced. The configurations themselves served as "measuring devices". Pressure acceleration and strain were also measured. Damage to some JANGLE structures within 1,000' of GZ was also inspected.(Dohrenwend 1958: 5, 17,21, 25; Jackson 1993: 13-8)

3.3.2 The loads applied to buried structures by an underground detonation and the response of these structures to the loads were examined. Two buried four-walled structures without floor or roof were tested at 200' and 250' from ESS's GZ. The outside dimensions of the structures were 12'6" square by 8'10" high, and the 4 walls (front and rear walls 24", side walls 12 ½" thick) were cast in place in an open cut that was subsequently backfilled so that its top was 3'9" below the original ground. The "solid" structures were instrumented for transient load and response data and for permanent displacements and strains. This project was closely coordinated with Projects 1.6 and 1.7.(Sinnamon 1957: 5, 11, 15, 24-5)

3.4 This project on MET used the same structures as UPSHOT-KNOTHOLE 3.8. Only the minimum data required for the structural response of the roof beam strips was taken.(Woodring 1957: 5, 16, 26)

3.6 investigated the degree of protection that earth cover offers to an above ground structure. The corrugated steel 25' arch ammunition magazine (like a Quonset hut) used in UPSHOT-KNOTHOLE 3.15 was reused, with some modifications*, at 2,300' from MET GZ. It had no earth cover. A similar structure was constructed at 1,500' and covered with an earth berm that had a trapezoidal cross section. The volume of earth was approximately 2,400 cubic yards, and it was tamped to a height of 8'. In addition, 6 models about ¼ the size of the two 25' arch structures were constructed of corrugated sheet metal: 3 of steel and 3 of aluminum. These were located at 1400, 1500, 2000, 2000, 2500, and 3000 feet and also had earth cover which was wetted but not tamped. Instrumentation consisted of 9 deflection gages.(Vaile 1956: 3, 11, 14-7, 21-2, 25) [*Footnote: A cross tunnel construction had been removed from the UPSHOT-KNOTHOLE 3.15 building.] Vaile (1956:27) states:

> Incontrovertible evidence was found that a cat had scrambled on the hot tin roof of this building. Tracks were apparent in the thin layer of soil close to the crown and clear scratches were found in the galvanizing of the steel itself. Extensive questioning of witnesses established that the cat was a D8, weighing 40,000 pounds, which had been driven onto the building during the removal of the cross tunnel.]

3.7 investigated the effect of the length of the positive phase of blast forces. Four structures each 30' high and 40' in width, like small industrial buildings, were exposed on MET at distances of 3600', 4350', 5000', and 5730'. Instrumentation provided transient structural deflections, strains, accelerations, overpressure-time, and dynamic pressure-time.(Sinnamon 1958, 5)

3.8 Fourteen plain and 4 rib-reinforced concrete panels were tested at 3800' and 4850'. The panels were all 20' long with a 1' or a 5' height. The depth of the plain panels was about 9", the ribbed were about 11" deep. The panels were affixed to a foundation for exposure.

Pressure, deflection, acceleration and strain measurements were made.(Allgood 1957: 9, 20, 23, 28; Jackson 1993: 13-9)

PLUMBBOB

All PLUMBBOB structures Projects were conducted only on Priscilla.

3.1 was conducted to determine the suitability of underground concrete arches for use as protective shelters in the 50 to 200 psi range. Four reinforced-concrete arch structures were constructed underground such that the top of their crowns was 4' below the surface. They all had semicircular cross sections, with an inside radius of 8' and a thickness of 8". Three were 20' long, and one was 32' long. The 32' and one of the 20' structures were placed where ground-surface overpressures of 50 psi were predicted. The other two were placed at 100 and 200 psi. Measurements were: electronic - overpressures, deflections, accelerations, earth pressures and strains; and self-recording - air overpressures and deflections. Gamma film badges and neutron chemical dosimeters were used to determine the degree of radiation protection the structures afforded. Styrofoam missile traps were installed to determine the quantity and size of the missiles generated by the ground shock and spallation of the inside surfaces. To assess damage, level and transit surveys were made as were photographs and visual inspections.(Flathau 1959: 13, 17,30-2)

3.2 To determine the amount of protection they would provide to persons, 12 commercially available corrugated steel and precast concrete, large diameter, 20' long conduit sections were placed underground. The 5 concrete conduits were circular in cross section with an 8' diameter. The steel conduits were "cattle pass" shape (like an egg but somewhat flatter on the bottom), with heights of 7'8" and widths of 5'10". They were placed with their length perpendicular to the blast at depths of 5', 7.5', or 10', at 4 ranges from GZ, 970', 1040', 1,150, and 1,360' where predicted overpressures were 50, 75, 125, and 150 psi. Measurements consisted of: deflection gages at the top of all conduits; self-recording pressure-time gages on the earth surface above 4 conduits; peak internal pressure and peak vertical acceleration in all conduits, and dynamic acceleration in 4 conduits.(Albright 1960: 13-5, 21, 26)

3.3 Three corrugated steel arch structures were constructed underground with 5' of earth cover at the Project 3.2 test bed: 2 at 1,325' and 1 at 1,150'. Measurements were: air pressures, peak internal pressures, maximum and dynamic accelerations, and deflections. Particular attention was given to items defined as personnel environmental hazards inside the structure, e. g., spall, missiles, and dust. Gamma film packets and chemical neutron dosimeters, and neutron threshold devices were also placed in the shelters. A blast closure valve was examined for capabilities in a blast environment, and open pits were investigated for providing blast protection of power generators.(Albright 1961: 11-15)

3.4 utilized structures remaining from Operations UPSHOT-KNOTHOLE and TEAPOT to obtain data on their blast loading and response. Some minor rehabilitation was done as needed, but nothing major. Pre and postshot surveys were made of the buildings as were photographs. Free-field pressures were measured by BRL self recording gages. A few measurements were made that repeated those in the original test such as deflection. Observations were also made of existing structures in Frenchman Flat and Area 1 of Yucca

Flat where damage was anticipated from Priscilla. A series of concrete panels were the only new items tested, and their behavior to thermal radiation was investigated. The report of this project is detailed in its description and figures of the structures both pre and post Priscilla.(Bultmann 1960b: 5, 20)

3.5 Two test structures and one comparison structure were used in this initial study of the benefit derived from a backfill that isolates the underground structure from ground motion. Each structure was placed in a hole of diameter 5 1/2' and 15' deep with its top about 2' below the surface. Around the sides and bottom of the 2 test structures, glass bottles were used as backfill. One test structure and the comparison structure were placed at 750' from GZ, the other test structure was at 1,050'. With glass bottles (which appear to have contained alcoholic beverages), the peak vertical accelerations were about 28% of the free field.(Vaile 1960: 5, 11, 21)

3.6 Ten dome and arch structures were constructed and used by the Air Force and OCDM to determine blast loading on dome structural response. The structures used fall into two general categories:
nonresponding structures – to measure the distribution of the blast load over the surface of the structure.
responding structures – to determine the response motions of the structure resulting from the blast load.
The ten structures were large and represented significant construction and instrumentatiuon efforts.(Bultmann 1960c: 5, 15-6)

Structure	Config	Type *	Const Mat **	Diam Or Span (ft)	Len-gth (ft)	Height (ft)	Shell Thick (in)	Dist From GZ (ft)	Pmax (psi)
USAF Project 3.6									
9027.01	Dome	N	Rconc	50	-	11.67	24	1180	70
9027.02	Dpme	N	Rconc	50	-	11.67	24	1600	35
9026.01	Dome	R	Al	20	-	4.13	1	1180	70
9026.02	Dome	R	Al	20	-	4.13	½	1180	70
9028.01	Arch	N	Rconc	34	90	10.25	12	1180	70
9028.02	Arch	N	Rconc	34	90	10.25	12	1600	35
FCDA Project 30.1									
8001.01	Dome	R	Rconc	50	-	10.7	6	1180	70
8001.02	Dome	R	Rconc	50	-	10.7	6	1600	35
8001.03	Dome	R	Rconc	50	-	10.7	6	2030	20
8008	Door	R	Ssteel	-	10.58	8	-	1600	35

* Type: R = responding structure; N = Nonresponding structure, see above table.
** Construction Material: Rconc = Reinforced concrete; Al = Aluminum; Ssteel = structural steel

A door similar to the one tested as 8008, had been in use by the Air Force in much larger structures. However, this was the first time such a door was tested with a nuclear blast.(ibid.16) Except for this door, all of the test structures were of much smaller dimensions

than structures proposed to accomplish the anticipated military and civilian functions. Also, the structures were located at pressure levels below those of current interest at the time. No modeling or scaling laws were used in their design. "They were designed by the same methods proposed for use on much larger structures; the presumption was that if the design methods were successful for the small test structures, they could be applied with confidence to larger designs."(ibid.18)

There was extensive instrumentation of the structures with over 200 gages. The nonresponding concrete arches used 19 and the nonresponding concrete domes used 24 pressure gages, with a mix of electronic and self-recording gages. The responding concrete domes used electronic pressure and deflection gages and along with shear strain, strain, vertical acceleration, mechanical drum gages*, and mechanical radial-rod deflection gages**.[Footnotes: *Mechanical drum gages measured "the change in shape of the base circle of the dome during blast loading". **Mechanical radial-rod deflection gages provided "a maximum and minimum record of the shell movement".] (ibid.58)]

The responding aluminum domes specialized in electronic and mechanical displacement gages and strain gages.(ibid 50) At the 35 and 70 psi regions, free field pressure measurements were also made. Around the foundation of the responding concrete dome located at 70 psi, 24 soil test soil test holes were drilled and filled with colored sand. Post shot these holes were excavated and the relative motion of the soil was determined (like work done at ESS crater). Two cameras were placed inside the 1" thick responding aluminum dome to possibly record deflections of the dome.(ibid. 58-9)

H: MEASUREMENTS and INSTRUMENTATION DEVELOPMENT for THERMAL AND NUCLEAR RADIATIONS

Ha. Thermal

BUSTER

2-4-1 The DoD fielded a "thermal line", which ran between 2,000 feet and 12,000 feet from the intended ground zero (IGZ) of Able and Easy. Calorimeters and other sensors were placed along this line for the measurements of thermal intensity vs. time and total thermal outputs. Shots Able and Easy had 5 stations along this line, and the other shots had 6 stations. A motion picture film of the thermal line showed that " ... large quantities of smoke or dust appear long before the arrival of the shock front ... " (Broido 1952: xi)

TUMBLER-SNAPPER

8.2 NRDL obtained measurements of air temperature versus time at the elevations and distances where blast measurements were made. Instruments were installed along a line 25' from the blast line and parallel to it for the shots Able, Baker, Charlie, and Dog. They were at ground level and mounted on steel towers at 10' and 50', the same as the blast measurements. The temperature measurements were made at only about half of the blast stations, but they were "designed, fabricated, calibrated, and installed in a period of approximately two months".

"—results indicate that the rapidly fluctuating temperatures produced by the detonation vary markedly from point to point at the same distance from point zero. Severe pre-shock temperatures occurred above grade level only where the incident thermal radiation was sufficient to produce 'popcorning', i.e. exploding of sand by the absorption of thermal radiation."(Broida 1952: 3, 13-20)

8.3 NRDL also obtained measurements of total thermal radiation and intensity-time on Able, Baker, Charlie, and Dog. Instruments were placed at stations along the thermal line from GZ to 9000'; along the Forest Service line from 11,000' to 20,000', at stations where aircraft were parked, and in the drop aircraft. "Total thermal radiation measurement made near the ground indicated that, even before the arrival of the shock wave, serious obscuration is produced by ---- 'popcorning' of sand, and smoke produced by the burning of ground litter. The thermal energy received by 'the drop aircraft' was appreciably greater than that received at equivalent distances along the ground. This increase is primarily due to reflection by the ground." (Broido 1953: 3, 14-21)

8.3a On Charlie, evaluation was made of passive thermal indicators, in the form of semicircular wood discs on which a heat-sensitive medium that responds to the thermal radiation was mounted. It was thought that the thermal indicators might be used to determine the direction of a detonation and that several measurement locations might be used to establish GZ. Such simple indicators would have application in many military tactical and civil defense situations.(Banet 1953: 7)

8.7 was conducted by UCLA to gain experience with instrumentation for a measurement of thermal radiation being developed for Operation IVY. The instrumentation was installed at Site 400, Mercury; and the distances from the instrumentation to the GZs was: Fox 11.56 mi; George 8.22 mi; and How 14.72 mi. Some qualitative data was obtained which suggested that "at peak irradiancy from the fireball, the distribution of energy is similar to that of the sun under specified conditions". (Romie 1962: 7,19,24)

<u>UPSHOT-KNOTHOLE</u>

8.2 Light exerts a pressure. This project was based on the hypothesis that it is possible to measure the intensity of light by the mechanical effect its pressure has on a highly reflecting surface. A radio-frequency oscillator circuit was developed and placed in a vacuum. The mechanical pressure of the light changes the frequency of the oscillator. This change in frequency was detected by means of an appropriate receiver and related to the pressure. Participation was on all shots except Climax. Sensing elements were placed at distances ranging from 5,309' to 10,568', and two manned stations were located at distances between about 6.5 and 13 miles.(Bohn 1954: 3,11)

8.10 On Ruth, Dixie, Encore, Grable and Climax, measurements were made on the ground at different distances from GZ of: thermal energy, the shape of the thermal pulse, its spectral distribution, the energy reflected from the ground, and the energy scattered by the atmosphere. On Dixie and Grable, some measurements were made from two B-50 aircraft. Calorimeters and foil radiometers were used for these measurements as well as those

supplied to Projects 3.9, 5.1, 5.2, and 8.1. On Grable, total energy measurements as a function of direction were made under smoke layers in connection with Project 8.4.

In areas where "popcorning" might occur, the instruments were placed on towers at 50' above ground level, and at 10' above the ground in other areas. The following table summarizes the scope of instrumentation:

Shot	# Stations	Total # Calorimeters	Total # Radiometers
Ruth	2	20	4
Dixie	2	20	4
Encore	7	56	11
Grable	7	65	10
Climax	3	30	6

(Guthrie 1954: 3, 14-8)

TEAPOT

8.3 evaluated the effectiveness of an oil smoke screen in attenuating the thermal radiation on Hornet. Smoke generators created a screen about 80' to 90' high over 4 of the 5 instrument stations located at 1,000', 1,400', 1,900', and 2,400'. Attenuation of 78 to 90 percent of the radiant energy was obtained.(Engquist 1956: 3)

8.4b NRDL conducted basic thermal radiation measurements from stations at ranges as close as feasible to GZ on: Wasp (at 2 stations), Moth (2), Tesla (2), Hornet (1), Bee (2), and Wasp' (2). On HA, one station was 2,000' east of GZ and the other was at 34,216' south. Results indicated that there are significant differences in thermal properties between tower and air bursts. "The air bursts have higher thermal yields, higher peak irradiances, higher peak temperatures, and different pulse shapes than tower bursts." The thermal properties of an air burst vary with altitude. "The higher the altitude, the shorter the time scale, the larger the fireball, and the lower the thermal energy. The peak temperature is little changed."

On MET measurements were made over: water, asphalt, desert, concrete, fir boughs, Ivy, painted wood, and soil. NRDL also supplied more than 300 thermal instruments, used in projects 5.1, 5.4, and 5.5.(Hillendahl 1959: 5, 18-9)

8.4c attempted to measure the radiant energy delivered prior to the first minimum by using a calorimeter of improved sensitivity and time response. The measurements were to be made on two detonations. However, instrument failure occurred. (Hopton 1957: 3, 7, 14)

8.4d tried to determine if there was any significant difference in spectral distribution between the thermal radiation of a high-altitude air burst and a low-altitude detonation of the same device. Measurements were made with a prototype spectrometer on nine shots, and some data was obtained. However, the prototype instrumentation did not function as desired, and the spectral difference wrt altitude was not determined. (Plum 1958: 5, 9, 11, 15, 20-2)

8.4e Air temperatures were measured by NRDL prior to airblast arrival at heights of 1/2, 1 ½, 3, 5, and 10 feet at the 2000' stations at which were located ivy plants, fir boughs, wood, and concrete. The maximum air temperatures above ambient were unexpectedly found to be in excess of 1,500°C over all of the plots. The results indicated a definite trend of lower temperature with an increase of height, and there were indications that the air was not uniformly heated.(Inn 1957: 3, 14-5)

8.4f measured thermal radiation as a function of time on 9 shots, but primary emphasis was given to Wasp, Wasp', and HA. From the time dependent records, the variation of effects wrt altitude were examined such as time of first peak, time of minimum, and total energy in first pulse.(Jenkins 1958: 5, 22)

<u>PLUMBBOB</u>
8.3a A prototype high-speed (100 microsec) streak spectrograph for obtaining early-time spectra of bomb light was successfully field tested on Lassen, Wilson, Priscilla, and Diablo. This instrument was being planned for use during Operation HARDTACK I. (Plum 1957: 5, 11-1)

<u>HARDTACK II</u>
2.12d Radiant exposure (cal/cm^2) was measured for Hamilton at 8 ground stations ranging from 175' to 700' on a radial from GZ. Two independent calorimeters were used at each station, and the instrument shelter was located at 1000'. (Mahoney 1960: 23-5)

8.8 For low-altitude detonations of low yield nuclear devices, measurements of: total thermal radiation (energy/area, joules/cm^2) were made with calorimeters; and irradiance (energy/area-time, joules/cm^2-sec) were made with a bolometer and a spectroscopic detector. Both of these quantities were measured as a function of time and of wavelength of the radiation.(Reed 1962: 5, 18-21,33-6)

In addition, 4 different spectroscopic detectors measured irradiance in four different ranges of wavelengths. The calorimeters and bolometer measurements included the range of all of the spectroscopic detectors and longer wave lengths as well. This "overlap of data" enabled comparisons, as well as providing energies in specific ranges of wavelengths. The wavelengths measured were in the visible region.(ibid., 13)

"Wherever practicable, two sites were instrumented for each event."(ibid. 18) Participation was on 11 events: 6 events were between 1.2 tons and 188 tons (Hamilton and Humboldt, Quay, Rio Arriba, Wrangell, and Rushmore); Manzama had Zero yield; and 4 had yields between 1.3 and 6.0 kt (Santa Fe, De Baca, Sanford, and Socorro). (ibid. 32-3)

Hb. Nuclear Radiations
<u>JANGLE</u>
2.1a ESL and NBS (National Bureau of Standards) measured gamma dose rate as a function of time with electrical equipment at: 27 stations located between 1000' and 15,250' from Sugar GZ and 29 stations located between 2000' and 14,000' from Uncle GZ. The

pattern of stations was along 6 azimuths with at least one in each quadrant. The stations within 4000' (about half the stations) contained 2 instruments each. The second, or pop-up unit, was initially below ground and had greater sensitivity than the first or fixed unit. It was popped into position by an elevator at about +10 seconds. The single-unit instrument shelters were 4'x6'x4', and the doubles were 6'x6'x6'. They were pre-cast of high strength concrete 2" thick, shipped to the site, and emplaced underground with a 12" thick top slab. Sliding and rolling hatches in the top slabs provided access. The detectors were mounted in the roof slabs, and the shelters contained the bulky electrical equipment, including batteries. Eighty-six transmission lines were run from the shelters to the large 20'x40' recorder station, and 36 additional lines were run as spares and telephone lines.

Eighty-three of the 86 instruments performed properly. The dose rate versus time data curves were integrated out to different times to obtain total dose up to times of 10 min, 1 hr, and 10 hrs. Iso-dose contour plots were also obtained at these times.(Costrell 1952: 1-4, 42-44, 46, 51).

2.1b Five droppable units capable of telemetering data on gamma activity were emplaced on the ground (not dropped) pre-shot at distances between 1000' and 3000' from Sugar and Uncle GZs. Between 0 to +15 min post shot, their signals were monitored by ground-based receivers and by the project's P2V-2 aircraft circling nearby. Post shot, 2 additional units were dropped from the aircraft in and around the craters of both Sugar and Uncle; but they failed to operate.(Caris 1952: vii, 1-2, 26-8)

2.3-1 "Gamma rays affect a photographic film much like ordinary light, and consequently, gamma ray photography has much in common with ordinary optical photography". "-- film can be used to record total gamma dosage, including both initial and residual gamma radiations". About 200 photographic films of graduated sensitivity were placed in NBS film badge holders. About 100 holders were placed each on Sugar and Uncle in about 10 radial lines at different azimuths. They were also placed in foxholes, tanks, and structures. For Project 2.7, film badges were placed in animal cages located along arcs at 2500', 5000', and 8000' from GZ.(Forbes 1952b:vii, 19, 25)

<u>TUMBLER-SNAPPER</u>

2.1 On all of the tests except Able, the total dosage of gamma rays was measured. Photographic films of graduated sensitivities were placed in NBS film holders at varying distances along a radial line from GZ. The holders which each contained two film packets, were placed on aluminum stakes that were recovered approximately 3 hours after each detonation. For Baker, the holders were placed between about 500 – 2000 yards from GZ. For the other six shots the holders were placed between about 1200 – 3000 yards.(Larrick 1952: 3, 7, 9, 21-7)

2.3 provided measurements of neutron flux for the interpretation of biological studies and the study of neutron dosimetry techniques. Three different measurement techniques were used at various ranges from GZ to measure neutron fluxes in different energy bands.(NRL 1980: 5, 7, 18-20)

UPSHOT-KNOTHOLE

2.3 Standard neutron absorption and activation techniques using gold, tantalum, and sulfur absorbers were used by NRL to measure the neutron environment during Simon, Encore, and Harry.(Jackson 1993: 11-4) The absorbers were placed on stakes and cables at various distances from GZ before the shots and recovered postshot.(Ponton 1982a: 92)

TEAPOT

2.1 used dosimeters of photographic films of 5 sensitivities to measure the initial gamma exposures as a function of distance on all shots except the last 2. The dosimeters were generally placed at 100 yard intervals between 280 to 2,400 yards from GZ. However, on ESS (the cratering test), considerably more dosimeters were used in close, and they also extended to distances out to 18,000 yards. On HA, dosimeters were placed in 15 drop canisters provided by Project 1.1.(Graham 1959a: 5, 12-3)

2.2 measured the neutron energy spectrum as a function of distance by using detectors employing gold, sulfur, plutonium, neptunium, and uranium-238. The detectors were placed on either: 1) ¾" steel cables mounted ~4' from the ground and running from 100 to 1,000 yards with detectors clamped every 100 yards; or 2) 2" steel stakes to which an 18" crossbar was clamped. Early and rapid recovery is important for the fission threshold detectors. Recovery was rapid consisting of simply unclamping the detectors on cable and the crossbar from the stake. Measurements were made on all shots except the last two, and "primary emphasis was placed on measurements of identical devices". As in Project 2.1, these detectors were also placed in the 15 canisters of Project 1.1.(Hanscome 1958: 5, 9, 13,-6)

2.7 Shielding against gammas and neutrons was examined in foxholes, vehicle trenches, armored vehicles, field fortifications, and underground and surface blast resistant structures (already existing at NTS). Instrumentation used for the effects of gammas was film and chemical dosimeters; and for neutrons, fission threshold detectors and sulfur and gold detectors were used. The main shots instrumented were MET and ESS. On MET, instrumentation was placed in:

- 12 personnel and instrument shelters, on the surface and underground, and located between 900' and 6000' from GZ.
- field fortifications: 9 Army corrugated steel shelters, 14 ERDL emplacements, and one chemical, biological, and radiological (CBR) protective shelter. These fortifications had at least 5' of earth cover and were located at 333, 383, and 467 yards from GZ.
- 12 fox holes of different sizes orientations and locations between 489 and 3,000 yards from GZ.
- 3 vehicle trenches at: 533 yards with caterpillar tractor bulldozer and grader; 700 yards with caterpillar tractor bulldozer, grader, truck mounted crane, truck mounted air compressor, and a generator; at 900 yards with truck mounted crane, truck mounted air compressor, and generator.
- armed vehicles consisting of: an AIV-M59 8 man personnel carrier; a self propelled 155-MM Gun, T97, with 6 crew positions; and 3 M48 tanks with 90-MM guns.

Foxholes were instrumented on Tesla, Post, and Apple 2. The armed vehicles were instrumented on Wasp, Turk, Hornet, Apple, and Apple 2. On ESS, 20 underground

structures located from 235' to 1,038' from GZ were instrumented as were 2 foxholes at 5,000'.
(Hendrickson 1957:3-4, 15, 21, 30-7)

PLUMBBOB

2.3 About 1,500 neutron flux and spectral measurements were made using gold, plutonium, neptunium, uranium, sulfur and other detectors at different ground range. Detectors on the ground were all cable pulled for retrieval. Participation was on Franklin, Lassen, Priscilla, and Owens, each of which used10 ranges for detector placement; John with 12 ranges; and on Smoky where 39 ranges were used to examine the effects of hills and dales.

Neutron flux, spectra, and dose measurements were provided to other projects: **2.2** neutron fluxes as a function of depth in soil; **2.4** ,17 sets of detectors were emplaced in M-48 tanks, Ontos vehicles [self-propelled 106-mm rifle, M50], and steel armor hemispheres; **2.9** detectors in the delivery aircraft plus two other aircraft; **2.10** neutron measurements at various heights above ground by detectors supported by balloons; **3.1**, **3.2**, and **3.3** in underground structures and field fortifications; **41.3** neutron measurements at different heights above ground; and for **39.5** additional measurements on Smoky. (DASA 1960c: 5, 11, 16-20)

2.5 Initial-gamma intensity versus time and distance both on the ground and in the air was measured between 1 msec and 20 seconds on 6 shots: Boltzman, Franklin, Lassen, Wilson, Hood, John, and Owens. Seven stations were set up in Area 9 for all of the shots except John. These stations ran from the GZ of the balloon shots in Area 9, for 7,500', southeastward at an azimuth of 163° 42' 49.5". The ground instruments were emplaced on D-2 and D-1, recovered after each shot, and recalibrated. The Project 2.10 balloons were launched on D-1 and were at a height of about 950'. The electronic instrumentation was suspended about 8' below each balloon. Because radiation and blast destroyed the balloons, data acquisition was limited to the interval between t=0 and impact with the ground which destroyed the instrumentation.
(DASA 1961b: 5, 15, 21-3)

In support of Project 2.1, neutron induced gamma-rate measurements were made on Owens at stations that ran SW of GZ on an azimuth of 204° 00' 00" at ranges of 200, 300, 400, and 500 yards from GZ and 30' laterally from the stations. The instrument systems were 11 feet high and weighed 300 lbs. A 2 ½ ton 6-by-6 truck with monorail and a ¼ ton truck with A-frame were required to install and recover the equipment.(DASA 1961b: 89-90)

2.10 To determine the effect of the air-ground interface on initial nuclear radiations, extensive measurements were made of:
total gamma dose (by 3 types of film badges, 2 types of phosphate glass dosimeters, quartz dosimeters, and chemical dosimeters). At each station, from 2 to 4 types of dosimeters were used. The instrument stations were located at heights of 0, 3, 10, 30, 50, 100, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, and 950 feet above the ground along the single mooring cable of a balloon. The balloons were General Mills Aerocaps about 31' long and 11' in diameter which were destroyed by the thermal radiation and blast of the detonation.

<u>gamma dose rate</u> (by saturated ion chambers carried aloft by balloons). Balloon-borne gamma-rate stations were employed; 4 each on: Lassen, Hood, and Wilson, and 6 on Owens. The balloon moorings were spaced at increasing ranges from GZ. (ibid. 16)
<u>neutron flux</u> (by sulfur pellets and nuclear track photographic emulsions as detectors plus a few fission foil detectors). The neutron detectors were packaged in the same manner as the gamma dosimeters and placed at the same locations of the balloon mooring cables.
<u>neutron dose</u> (by chemical detectors). The primary participation was on Lassen, Wilson, Hood, and Owens which used the balloon moorings. John also used a balloon moored at 5,000' over GZ. Participation was also on 3 other shots that used towers rather than the balloons: Boltzman (300' tower), Diablo (2 towers of 500'), and Kepler,(1 tower of 500').(York 1960: 4, 14-18)

<u>HARDTACK II</u>
2.12a had 4 measurement objectives:
1) neutron flux and dose at different ranges
2) neutron, gamma and thermal radiations up to an altitude of 1,500'.
3) dose measurements for Project 4.2 (swine), and
4) neutron flux and spectrum for Project 2.12c (induced activity in soil).
Participation was on Hamilton and Humbolt which had planned to use the same GZ; but due to a change in Humbolt's location on D-1, activities were severely limited. Objective 2 which used balloons was not achieved on HARDTACK II.
<u>Hamilton</u>
At azimuths of 150° and 330°, ¾" cable rope was laid, and threshold detectors of sulfur, gold, uranium, neptunium. and plutonium, were clamped and taped on it. Along the 150° azimuth, 11 detectors were placed between 30 and 800 yards from GZ; along the 330° azimuth, 5 detectors were placed between 22 and 325 yards. Postshot, trucks were used to pull the cables to a radiologically safe area where they were unclamped and were taken to a mobile laboratory in the forward area. In support of 2.12c, 3 detectors were used; and for Project 4.2, 15 detectors were place in tanks, offset foxholes, open foxholes, and animal containers. Ten of these were surgically inserted in the pigs.

The threshold detectors, their energy thresholds and reactions were:

Detector	**Energy Threshold**	**Reaction**
Gold	Up to 0.3 ev	Au^{197} (n,gamma) Au^{196}
Pu^{239}	10 kev	Fission
Np^{237}	0.63 Mev	Fission
U^{238}	1.5 Mev	Fission
Sulfur	3.0 Mev	S^{32} (n,p) P^{32}
Zirconium	12.3Mev	Zr^{90} (n,2n) Zr^{89}

(Rigotti 1960: 14)]
About 26 chemical dosimeters were installed on goal-post stations along these same azimuths as well as along the 240° azimuth. These and the detectors in tanks, foxholes and animal containers were recovered by personnel.
<u>Humbolt</u>
Only one azimuth was used. Detectors were also placed in foxholes located between about 5 and 20 yards, and in animal enclosures at about 25 yards.

(Rigotti 1960: 23, 21, 25-27)

2.12b had 3 measurement objectives:
1) gamma-dose for Project 4.2 (swine)
2) initial gamma dose versus ground range, and
3) residual radiation intensities in the field and decay rates.

Participation was again on Hamilton and Humbolt. Postshot on both events, gamma field surveys were also conducted.

<u>Hamilton</u>

Four Incremental-Gamma-Dose Recorders were used. An IGDR was about 10' high and 17" in diameter. It was placed about 8' underground with about the top 2'-3' exposed above ground. It is "essentially a conveyor belt of film badges each of which is exposed in turn from an underground shield and returned thereto". Its start, stop, and speed can be set thereby enabling it to provide for different exposure times.

Also, 96 film badges were placed on a grid with azimuths every 30° and radial distances every 100 yards out to 800 yards. In support of Project 4.2, 147 film badges were used.

<u>Humbolt</u>

Film badges were hurriedly placed in conjunction with foxholes and animal containers.(Maloney 1960: 9, 13-8)

2.12c An attempt to determine the extent and duration of the radiological hazard due to neutron-induced activities in soils was planned for Hamilton. However, due to a change of shot location from Area 7 to Area 5, the samples obtained from Area 7 preshot were not satisfactory for the field/laboratory comparisons that were planned. Also, an example of how everything can go wrong: " -- two methods had been planned for obtaining early field dose rates: Automatic, pop-up, gamma-dose-rate recorders had been installed, but they failed because of shock damage. An aerial survey helicopter was prohibited entry for about 2 hours after the shot because of a heavy dust cloud. Hamilton went at a lower yield than anticipated which resulted in the dose rates on the ground being correspondingly low". However, later time surveys were successfully made.(Wilsey 1960: 9, 15-8)

2.13 On Hamilton, film badges and other equipment were placed from 0 to 600 yards from GZ along the same 330° azimuth line as used by 2.12a. The badges were placed inside 3" steel pipes that were attached to the pull cable used in 2.12a. The cable was pulled back within about H+5min, so the badges were not exposed to induced or fallout activity. Film badges and other equipment were located on stakes from 300 to 1,600 yards from GZ on the 330° azimuth and on another azimuth line at 50°. Some were recovered within minutes and others took up to 2 hours after detonation.(Griesmier 1960: 5, 12, 14)

I: RADIAC AND IBDA INSTRUMENTATION DEVELOPMENT, EVALUATION, and TRAINING

Ia. RADIAC (RAdiation Detection, Indication, And Computation) Equipment Ground and Ariel Surveys, Evaluation, and Training

BUSTER

6.1b A variety of dosimeter types developed by the Navy and Army for use by military personnel in areas of high dose rates of prompt radiation were evaluated on Baker, Charlie, and Dog.(Cryden 1952: viii, 1-5)

6.4 Both the Navy and Air Force developed airborne radiac equipment to detect an atomic cloud at sufficient range for the aircraft to take evasive action. The Navy equipment was a microwave radiometric system, and the Air Force's was basically a scintillation crystal and photomultiplier tubes. The response of this equipment to GREENHOUSE's lowest yield shot (45.5 kt) had been marginal, at best. The lower yield shots of BUSTER were desirable for testing the equipment and setting a lower yield limit on its use. The P2V-2 and the B-17 radiac equipped aircraft were used. The report concludes, "further development of the two types of cloud tracking equipment is not recommended".(Terry 1952a: v, 1-4)

JANGLE

The two aerial surveys and one ground survey combined measurements with the evaluation of instrumentation on both Sugar and Uncle.

2.1c-1 used three instrumented C-47 aircraft to determine fallout and to test and compare various types of airborne instruments for instantaneous detection of radioactivity. The aircraft flew over the area downwind from NTS about 4 hours after each shot at about 600'. Intensity readings were relayed by radio to the CP where iso-intensity contours were plotted. The plots were not intended to be quantitative, but they "do effectively delineate the fall-out area and indicate the effects of terrain on the trajectory of low clouds". About 6000 mi^2 were covered within about 4 hours of flight time. At the request of the AEC, this project was also conducted as a service (not a project) during Operation BUSTER.(Harlan 1952: vii, 1-7)

2.1c-2 The Navy and Air Force both developed airborne radiac equipment to detect the presence of gamma radioactivity on the ground. The equipment measured the gamma dose rate at altitude, applied a correction for altitude, and indicated average ground intensity in areas on the ground. On the 2 JANGLE shots, the equipment was flown in the P2V-2 and B-17 which orbited about 5 miles from GZ at about 8000' and 10000' respectively. At about +1hour, the aircraft began ground survey operations at lower altitudes. The results were "satisfactory in principle", but the quantitative values were not accurate.(Terry 1952b: vii, 2,4, 17-20)

6.1 After JANGLE, 7 portable gamma radiac instruments were tested by Rad-Safe and this project's personnel from ESL and the Bureau of Ships. They were evaluated on the following features: ruggedness, dependability, maximum range, weight. Criteria developed for portable radiac instruments included: a maximum range of 500 r/hr; weight less than 10 pounds (preferably less than 5 pounds); and higher degree of ruggedness and dependability than existing light weight type instruments.(Forbes 1952c: 1-6)

TUMBLER-SNAPPER

2.2 After the shots Easy, George, Fox, and How, the contributions to total dosage made by gamma rays of different energies was measured by using radiac instruments. Four of the radiac instruments used in this program had the Lucite walls of their ionization chambers changed to aluminum, copper, tin and lead. The four wall materials had different atomic numbers and corresponding differences in their sensitivity to absorbing gamma rays of different energies. Thus, an approximation of the percentage of gamma ray dosage due to different energy ranges could be obtained.

When access was permitted to the forward areas, the radiac instruments were placed on tripods approximately 3½' above ground, pointed toward GZ. Readings were taken on the 5 r/hr, 500 mr/hr, and 50 mr/hr levels at various locations, between 0.35 and 1.4 miles from GZ. Readings were also taken at about + 31-32 hr; and if thought necessary, at a time later than +50 hr.(Ungar 1953: 3, 18, 22-3)

6.1 Eleven types of portable hand held radiacs were used by project personnel during survey exercises. The variety and diversity of these instruments was impressive. Evaluation was conducted by attaching the dosimeter to a standard x-ray film dosimeter at 14 stations along a line from GZ. The dosimeters were read as soon as practical after each shot. For self-indicating dosimeters, 5 to 10 people would read them to minimize human error. The evaluation grouped the equipment into the categories that: (a) "have reached developmental maturity", (b) "require further developmental work"; (c) "are unsatisfactory in their current form", and (d) were modified to eliminate current operational and maintenance troubles.

On George, an LC-126 aircraft flew a number of legs over a given point. Each leg was at a different altitude and a constant speed. Inside the craft, personnel had portable military radiac equipment and a stop watch to time the intervals for recording the radiac readings (5 seconds). Results, which were compared with readings taken on the ground by other means, indicated that "—it is possible to determine well within an order of magnitude, the contamination on the ground at a given spot".(Sisk 1953: 5-8, 1121, 41-5, 61-5)

6.7 Two types of air samplers were tested for adequacy and applicability to radiological air monitoring of the projected fall-out fields of Easy, Fox, George, and How. Four stations were selected from 5 to 6.5 miles N to NE of GZ for one sampler. The other sampler extended its range to Mercury, 33 miles. One sampler was found to require "additional modification", and the other was found not suitable because it was bulky (required truck deployment and hoists), fragile, and not shielded from background radiation.(Hardin 1952: 3, 27-30, 21-30, 42-8)

UPSHOT-KNOTHOLE

6.4 is a continuation of a part of TUMBLER-SNAPPER 6.1. Chemical type and 2 experimental dosimeters were evaluated.(Chaney 1955: 3,9)

6.8 Twelve types of RADIAC survey equipment were evaluated and information on their maintenance was obtained. Ten types of dosimeters were also evaluated. Participation was on all shots.(Johnston 1954: 3, 7-10)

6.8a The reliable National Bureau of Standards dosimeters were used to provide a basis for the evaluation of dosimeters conducted in Project 6.8. In addition, gamma radiation measurements as a function of distance from the detonations were made; and ground surveys were conducted by 150 personnel using radiac instruments.(Ponton 1982a: 114-5; Jackson 1993:11-10)

6.9 Naval airborne radiac equipment was flown in a P2V-2 craft, tested and evaluated on 5 shots. The airborne equipment consisted of: automatic recording dosimeters, ground intensity survey equipment, a gamma intensity telemetering system, and droppable gamma intensity pyrotechnic flares. These flares could be dropped from a survey aircraft. By means of an appropriately colored flare, it would indicate whether or not the ground intensity was above a certain level. A variation of this flare design was developed but not available for testing on UPSHOT-KNOTHOLE. It used a flashing light and could provide an indication of the level of gamma intensity. When the gamma intensity was between 0-5 r/hr, a white light started flashing, the amber light in the 5-50 r/hr range, and the red light in the 50-500 r/hr range.(Terry 1953: 3, 16-7)

6.10 further developed and simplified the techniques that were used to perform rapid aerial radiological surveys like those conducted in BUSTER 6.4 and SNAPPER 6.1.(Price 1954: 9)

<u>TEAPOT</u>

6.1.1a Radiac dosimeters were checked under 1) prompt and 2) residual radiations, by placing them in the field and recovering them. Rate meters were issued to radiological-safety teams and other groups who used the instruments to plot iso-intensity dose-rate contours. Also, a radiological calculator was evaluated. A set of initial conditions at a point in the fallout field was entered in the calculator, and it predicted the radiation intensity at that point at any later specific time. Evaluations were made on 7 tests.
(Cohen 1958: 9-10)

6.1.1b A radiological defense warning system consisting of blast, thermal, and gamma-radiation detectors was designed and tested successfully on 7 shots. It was designed to operate in the 1 psi overpressure region, where protective filters and other elements of a ventilation system would survive the blast.(Petriken 1957: 3, 7, 8)

6.1.2 measured the errors of standard radiac equipment by comparing it against laboratory types of gamma-ray standards taken to the field. It also measured the directional properties of radiation fluxes. Five types of portable rate meters, 2 gamma-ray "standards", a directional detector tripod with scanner, and data reduction equipment was used by the teams post shot on 3 shots.(Work 1957: 11,17,26)

<u>PLUMBBOB</u>

2.6 A newly developed gamma-neutron dosimeter was evaluated on shots Franklin, Lassen, Wilson, Priscilla, and Hood. The low yields of Franklin and Lassen resulted in non-usable data. However Wilson had a high neutron-to-gamma ratio and Priscilla and Hood had low neutron-to-gamma ratios. Significant information was gained from these shots. The system tested did not measure neutron dose satisfactorily.(DASA 1960b: 4, 17)

A new beta-gamma ion-chamber rate meter was also evaluated by Rad-Safe teams post Hood, using 24 instruments. Comparisons were made in the field with existing instrumentation. Further development was recommended.(DASA 1960b: 4, 31)

Ib. IBDA (Indirect Bomb Damage Assessment) Ground and Ariel Surveys, Evaluation, and Training

BUSTER

6.5 The USAF had a requirement for the development of an all-weather Indirect Bomb Damage Assessment (IBDA) system that would evaluate the effects of atomic weapons on enemy installations by the correlation of data that the strike aircraft could collect. In a conflict scenario this capability would assist the planning of follow-on strikes and eliminate the requirement for immediate reconnaissance missions. It was also thought that some of these types of techniques might also be used on the ground for the determination of GZ, height of burst, and yield.

The requirement rendered radar techniques attractive. Some measurements had been made in the Pacific, but the ability to detect radar returns from atomic explosions over inland terrain was not in hand prior to BUSTER. The IBDA radar sets were tested in two B-50D and one B-29 aircraft. (James 1952: ix, 1-3)

TUMBLER-SNAPPER

6.4 was a continuing activity conducted by three B-50D bombers flown by SAC on Able through Fox. They used radar and optical systems to determine bomb detonation position, HOB, and yield. Results indicated that sufficient accuracy was obtained for IBDA techniques to be useful. (Ponton 1982b: 95-6: Jackson 1993: 9-7)

UPSHOT-KNOTHOLE

6.2 On all tests of the operation, three B-29s operating from Albuquerque were at a distance of about 8-10 miles at detonation time. They used three types of radar sets and Mark III Bhangmeters for gathering IBDA data. An unsuccessful attempt was also made to investigate the electromagnetic wave emanating from the detonation to determine its HOB.(James 1955: 3, 15-6)

6.3 The Strategic Air Command (SAC) participated on all tests except for Ruth and Ray to test and further develop the current capability for IBDA. They established standing operation procedures and training requirements. Also, a training program was established, and SAC crews were familiarized and indoctrinated in atomic operations. This was NOT a "shoestring" operation!

Shot	# Aircraft/Type Actually Participating	# of Aircrew Persons	# of Technical Persons
Annie	12 /B-29	132	20
Nancy	12/B-36	204	20
Dixie	12/B-47	33	20
Ray	12/B-50	132	20
Simon	6/B-47 6/B-50	18 88	20 20
Harry	12/B-50	110	20
Encore	12/B-36 8/F-84	204 8	20
Grable	12/B-36 8/F-84	204 8	20
Climax	7/B-36	119	20

The report indicates the flight paths and formations used.(Keeling 1955: 3,15-9)

6.11 was the first opportunity for the Tactidal Air Command (TAC) to participate in an atomic test program. TAC used this opportunity to indoctrinate TAC fighter bomber and tactical reconnaissance pilots in the delivery and effects of atomic weapons. On Nancy, 33 pilots were positioned about 10 miles from GZ to learn about flash effects. During Dixie, seven T-33 aircraft carrying 14 pilots simulated a delivery maneuver. On Encore, a similar number of aircraft and pilots simulated a dive bombing delivery maneuver. About 2 hours after Encore, three RF-80 aircraft made 2 photographic runs over GZ for IBDA purposes. The pilots' reactions to these maneuvers is given in the project report.(Rawlings 1953:3)

6.12 Three methods for tactical determination of the location of an atomic detonation were tested on all of the shots: sound ranging, determination of the HOB by seismic means, and photographic flash ranging. Bhangmeter systems were also used to determine yield.(Tiede 1955: 3)

6.13 The Naval Electronic Laboratory's Fast Scan (20 scans per second) Radar was tested on 3 shots to establish its usefulness in determining relevant burst phenomena such as yield.(NEL 1955: 3)

<u>TEAPOT</u>

6.4 conducted an engineering evaluation of a complete Air Force IBDA system installed in a B-50D aircraft. The B-50 simulated a drop air-craft and was located 3 to 7 nm from GZ at t=0. Two F-84's were also used to determine the maximum geographical range of the yield-measuring part of the IBDA system. They were positioned at ranges of 35 to 153 nm from GZ. This program was conducted on all shots but ESS. It concluded that "this system could readily be adapted for use in current SAC aircraft of the B-36, B-47, and B-52 types.(Deegan 1957: 3)

6.5 This represented the Navy's first attempt to use unmodified naval radar sets to obtain IBDA radar-scope photography. In addition this project provided fleet personnel with

experience and analysis of IBDA data. It was conducted on 5 shots and concluded that "an interim IBDA capability may exist with present equipment with minor modification, provided ---".(Zirkind 1957, 3, 11)

PLUMBBOB

6.4 Before the days of Global Positioning Satellite (GPS), navigation relied on the LORAN (Long Range Aids to Navigation) system. Position was determined from the intervals between signal pulses that were received at 1 location (like a ship) from 2 (or more) widely spaced radio transmitters. Noral, the inverse of Loran, used 1 atomic detonation as the transmitter and 2 receiving stations spaced a goodly distance apart. The basic principal of both Loran and Noral is that the velocity of radio (EM wave) propagation is essentially a constant.

The difference in propagation time of the bomb pulse from GZ over 2 paths is a measure of the difference in length of the 2 paths. From this information, the location can be calculated. An IBDA system based on Narol was being developed and was tested on all of the shots except Shasta, Whitney and Morgan. Testing was examined in terms of yields, range, propagation path, and lightning (which can "mess-up" an EM measurement).. Receiver stations were set up at Albuquerque, NM (540 miles), Vale, OR (480 miles), and Rapid City, SD (830 miles).(Houghten 1958: 5, 11-3, 20)

HARDTACK II

6.14 evaluated the operational capability prior to acceptance of two types of automatic shutter-activating units for cameras. Participation was on 8 shots with cameras located at ranges from 2 to 18 miles from GZ for fractional-kt yields and from 7 to 60 miles for the larger yield shots.(Scarborough 1958 :9,10) These cameras were to be used in flash-ranging* instrumentation which was evaluated at sites 13, 17, and 29 kilometers from GZ. [Ponton 1982d: 39,94] [* Footnote: By using a known base line and three predetermined orientation points, it is possible to detect the location of "targets" by triangulation survey techniques. Flash ranging equipment consists of at least three battery-operated cameras mounted on tripods. If the target gives off a flash of light, as does a nuclear burst, the cameras can be actuated by a photocell. Such equipment can be used to determine location and height of burst of a nuclear detonation.] (Scarborough and Van Sant 1959)]

J: SERVICE OPERATIONS

Ja. Communications

BUSTER

6.9 The first known records of man-made disturbances of the ionosphere caused by the detonation of atomic weapons were taken on GREENHOUSE. On BUSTER, three sources of data were used to determine the effects of Charlie, Dog, and Easy on radio propagation at all frequencies:

1) Transmissions from -15 min to + 45 min after zero time from Alamo, NV were reflected from the ionosphere at a point nearly over GZ and received and recorded at Beatty, NV.

2) Ionospheric measurements were recorded at NTS from + 3 min to >+ 1 hr.

3) Observations were made of radio frequency noise in the vicinity of Beatty, NV from -5 min to + 5 min on an un-tuned antenna.

At NTS, a 65' antenna pole was erected on a hill about 7 miles from GZ and 1 ½ miles from the CP.(Stanford 1952: ix, 1-4)

TUMBLER-SNAPPER

9.4 both continuous and pulsed wave transmissions from Mather AFB in Sacramento, CA were used on all of the TUMBLER-SNAPPER shots to obtain data on the effects pf an atomic explosion in the ionosphere and the consequent effects on radio wave propagation. Receivers were located at: the NPG (Nevada Proving Grounds); Naval Ordnance Depot at Flagstaff, AZ; White Sands Proving Ground, NM; and Fort Sill, OK. "The observed effects were attributed to the local changes of ion density caused by the blast wave passing through the existing ionized layers." Radio propagation of only voice frequencies was disturbed for only a few minutes.(Daniels 1953: 3,9,13-6)

9.5 was designed to determine the wave shape and amplitude of radio frequency energy (50Hz to 100MHz) from a nuclear detonation. Two stations at 16 and 26 km were manned during the detonation; and additional stations were at White Sands, NM, and Evans Signal Laboratory in Belmar, NJ.(Ponton 1982b: 109; Jackson 1993:9-10)

PLUMBBOB

2.7 Radio wave attenuation in the vicinity of a nuclear detonation had been measured. This project provided a proof test of the techniques and equipment used prior to the shot John. The field installations consisted of: transmitting and/or gamma ray* measuring equipment, generally located near GZ; and receiving and general support equipment in a trailer van located at the Control Point building . [*Footnote: The attenuation of EM waves after an explosion depends on the number of free electrons present (i.e. their production rate, removal rate, and conductivity) The production of free electrons occurs when gamma rays interact with air. Therefore, by measuring the gamma ray production, one can obtain information about the rate of electron production.] Rudimentary protective bunkers with about 6' of ground cover housed the equipment near GZ, with only gamma ray detectors and antennas exposed. Participation was on 9 shots: Boltzman thru Priscilla, Hood, Kepler, and Owens.(Handscome 1962:11-2, 16-7, 21)

6.3 An A-4D-1 aircraft carried radio transmitters that were tuned to 6 different frequencies. At H+1 minute it was positioned so that the ionized cloud was directly between the aircraft and the ground-based receivers. Between H+1 and H+4 minutes, the aircraft was flown toward the ground receivers, keeping the cloud between the aircraft and ground receivers. The receivers consisted of 2 trailer vans housing duplicate receiving and recording equipment. The recorded radio signals were compared with recordings taken during a calibration run made immediately prior to the shot. The comparison provided a measure of the attenuation of EM energy propagated through the ionized cloud. This information was important for determining communication conditions in a nuclear environment. Flights were conducted on Franklin, Lassen, and Wilson. On Priscilla, a FJ aircraft was used for this purpose and for the purpose of checking the ability of a radar system to track an aircraft when the aircraft was 'behind' an ionized cloud".(Lee 1960: 5, 16-7,21)

<u>Jb. Decontamination</u>

<u>JANGLE</u>

6.2 This extensive project consisted of 10 individual projects undertaken by 4 military organizations: USNRDL, CRL, ERDL, and OCE. The 10 projects each used a set of decontamination methods on "targets" (exposed and/or contaminated materials commonly used by the military). All of the projects had objectives similar to these:

- determine the effectiveness of each of the methods used on the target(s).
- evaluate the methods used with methods used in other projects.
- determine time and manpower requirements for each method used.

"In addition, information was to be gathered pertaining to: individual and team health hazards inherent in the methods; disposal of contaminated waste resulting from the methods; and effectiveness of team training." The results of this work were aimed at developing nuclear design criteria for military equipment and construction.

Who - Project Title (pages of text)	Methods/Techniques Used On Targets-(Test(s))
USNRDL – Land Reclamation by Surface Techniques (pgs 5-23)	Scraping, plowing, harrowing, and filling were used with clearing* and modifying**of contaminated natural land area. [*clearing – removal of the contaminant from the area being tested.][**modifying – contaminant is mixed with the soil or buried under clean soil.] (Sugar)
ERDL – Land Reclamation by Barrier Techniques (pgs 24-31)	Post shot, within a contaminated region, barriers were constructed of 4 forms: a sunken roadway, a foxhole, a continuous trench, and a cleared circular area. The protection afforded to personnel occupying each of the forms compared to a person not being in the form, was evaluated as was a comparison among the 4 forms. (Sugar)
USNRDL – Flame Decontamination (pgs 32-48)	A Flaminator which incorporated: "a burner, a surface removal tool, and a vacuum pickup system was tested on wood, asphalt, and concrete surfaces". Its efficiency was compared with that of conventional surface removal, sweeping, and vacuuming techniques not employing flames.(Uncle)
USNRDL - Decontamination of Test Structures (pgs 59-85)	Three test structures were exposed 1 mile from Uncle GZ. Two were standard naval steel magazines (cylinders with oval cross section 14'highx20'wide). The third was a small wood frame structure 10'x12'x6'high. Surfaces of the structures were treated with variations of: Navy and Army standard paint, a strippable coating, a prime coat, and a varnish. Roofs were surfaced with tar-and-gravel and with roofing paper. Postshot, 3 common decontamination methods were used: water washing with fire hose; a mixture of steam, hot water, and detergent cleaning; and vacuum cleaning. (Uncle)
OCE -	Forty-five plywood panels, 4'x6' were constructed and

Decontamination of Construction Materials (pgs 86-101)	placed 7060' from Uncle GZ. Panels exhibiting wall construction materials were mounted vertically on a continuous "A" frame assembly. Roof materials were on individual frames aligned with slopes representing their normal pitch. 42 panels had wall and roof materials used in military installations. Each panel was in 3 parts, each of which used different protective coatings of primer (none or one of 7 types) and finish (none or one of 15 types) and in some cases an intermediate coat(none or one of 4 types). 3 remaining panels displayed geometries of different size, shape, or orientation. The decontamination methods used were: vacuum cleaning and high pressure hosing. (Sugar and Uncle)
OCE - Decontamination of Paved Areas (pgs 50-58)	By compacting rock and bituminous liquid, a road was constructed in individual sections 50'long and ~15'wide. The following methods were tested and evaluated: dry sweeping, vacuum cleaning, air hosing, water sprinkling, low pressure hosing, high pressure hosing, wet sweeping, and air and water hosing. (Uncle)
ERDL - Decontamination of Vehicles (pgs 162-180)	A variety of combat vehicles were used in this activity that included: Truck, ¼ ton 4x4 Command Reconnaisance; Truck ¾ ton, 4x4, Weapons Carrier; Truck 2 ½ ton 6x6, Cargo; Tank Medium M-26, and others. The tests were performed at a vehicle decontamination site located at the boundary of Rad Safety Red (Monitor required to accompany entering parties) and Rad Safety Green (Monitor not required). Equipment normally available in the field was used to establish the merits of different decontamination procedures and techniques, the team organization required, personnel hazards and times to conduct the work. Selected vehicle paints were used, and the shielding afforded by the vehicles was evaluated. (Uncle)
USNRDL - Measurements (pgs 181-194)	Measurements were made of initial contamination, of the movement of the contamination during decontamination, and of the residual levels after decontamination. Direct measurements of beta and/or gamma radiations were made. Radiac survey meters and beta counters were used. Also, indirect measurements were made by: sampling by a variety of techniques contaminated surfaces and aerosols, removing the samples from the field, measuring their radioactivity, and calculating back to determine what the values would have been at the times of interest. (probably Sugar and Uncle)
USNRDL - Contamination-Decontamination	Six experiments were conducted to obtain information on contaminability of surfaces with respect to their:1) orientation, 2) particle size of deposited contaminant vs

Phenomenology (pgs 102-138)	orientation, 3) surface roughness and hardness, 4) cleanliness, 5) solid particulate contaminants, and 6) different types of materials. A very wide variety and numbers of materials used by the military were exposed at 8 stations at ranges of 1000yd to 3000yd from GZ on Sugar and from 2000yd to 3000yd on Uncle. Wet and dry decontamination techniques were used in these experiments.(Sugar and Uncle)
CRL - Test of Materials (pgs 140-161)	The possible relationships between radiological contamination-decontamination characteristics and the physical properties (surface roughness, porosity and contact angle) of the surfaces of materials were studied. The types of panels used were:1) Like those used on GREENHOUSE with 23 different materials (ranging from coated steel to canvas ducking); 2) Chemistry panels of glass, polystyrene, stainless steel, and porcelain enamel; 3) Wood panels of yellow pine, maple, basswood, and oak; 4) Corps of Engineers 20 different construction materials with coatings; 5)Army Field Forces 7 panels of different construction metals and coatings; 6) Signal Corps construction materials with Army Spec. paints. On Sugar, all panels were exposed at 1 station which was not within the fallout zone. On Uncle, different sets of panels were exposed at 7 stations between about ½ mile to 14 miles; and 4 stations were contaminated.

(Earl 1952: full text)

6.7 To contaminate clothing, one lb of sifted contaminated soil from the Sugar GZ was placed with about 20 lbs of dry clothing into a contaminating tumbler. 360 lbs of trousers were thus contaminated and divided into 6 "loads", each containing identical numbers of cotton, rayon, and nylon trousers. Each load was monitored for contamination then laundered with a different "detergent". Also, different swatches of materials were contaminated and laundered as was other clothing used by personnel in Projects 6.2 and 6.3-1. A WWII standard field laundry unit made of stainless steel on a 10-ton semi-trailer type van was used as was a standard commercial wooden washer to determine if it became progressively contaminated. A key objective was to evaluate 6 experimental instruments for monitoring clothing contamination. The instruments were all tested with the same samples that included increasing amounts of contamination. (Hughes 1952: 1-12)

<u>TUMBLER-SNAPPER</u>
6.5 Methods and materials were assessed for the decontamination of aircraft flown on Dog, Easy, Fox, George, and How. The use of "gunk" (USAF Spec. 20015) and brushing techniques was found to be the most effective. Decontamination studies were also made of: different aircraft surfaces (oiled, polished, and clean); engines; distribution; and surface versus cockpit levels of contamination.(Teres 1953: 3-9)

TEAPOT

2.8a Complete surveys were made after all shots except ESS of contaminated airplanes that had recently flown through an atomic cloud. These readings were compared to a maximum dose rate that the most sensitive tissues of the human body would experience if contact were made between the body and the contaminated surface.(Crumley 1957: 8)

K: SUPPORT PROJECTS

Ka. Air Weather Service

BUSTER

8.2 The Air Force's Air Weather Service provided meteorological assistance during RANGER; and in March 1951, Brig. Gen James McCormack AEC/DMA (Division of Military Applications of the AEC) requested their support for BUSTER-JANGLE. This consisted of meteorological support for all tests as well as advice to the Test Director during the planning and operational stages. At a meeting at Los Alamos in July, Jack Clark "stressed the need for a completely operational weather station at the CP, with sufficient outlying upper air observing stations "to obtain wind values up to 25,000 feet. Cloud dispersion due to wind shear factors from 10,000 to 25,000 feet was important, and the proper general wind flow from 20,000 to 25,000 feet would assure the dispersion of the cloud. It was also desirable to have winds from the SW in order to move the cloud off into the sparsely populated NE quadrant." Clark "also stressed the need for cross-sectional analysis of pressure, temperature, humidity, and wind" velocity to allow proper evaluation of the effects of blast-reflection, which had been a problem on RANGER. This information would be obtained before each shot from the surface at GZ to an altitude of 1,500 feet. It ultimately required an instrumented balloon anchored near GZ that was capable of being raised and lowered by remote control from the CP. (Karstens 1951a and b)

TUMBLER-SNAPPER

8.4 measured the transmissivity of the atmosphere during Charlie, Baker, and Dog and obtained weather data such as: the barometric pressure, temperature, humidity, and rainfall which were pertinent in evaluating the results of other projects concerned with thermal radiation. A transmissometer was also constructed which enabled separate measurements of atmospheric attenuation in the ultraviolet and infrared wave length regions. (Derksen 1953: 3, 11, 15)

9.2 Like BUSTER 8.2.(Karstens 1951b)

TEAPOT

9.6 Similar to efforts conducted on previous operations. One F-84 aircraft performed local weather reconnaissance on all shots except Apple 2 at least 12 hours before each detonation.(Ponton 1981b: 114)

Kb. Photography

BUSTER

8.4 Technical photography was conducted for IBDA projects by Air Force Lookout Mountain; however, a report is not available.

JANGLE

4.1 Three C-47 aircraft were equipped with a variety of still and motion picture cameras that were installed in the door of the aircraft. Aircraft had pre-planned flight patterns and covered: 1) base surge and shock wave at ground position, 2) initial cloud growth and shock wave phenomena, and 3) technical documentary coverage for the entire cloud growth with respect to target layout. On both JANGLE shots: "The first cameras were started at -5 second and the opertation was completed nine minutes after zero time."(Crawford 1952: 1-2)

4.1a-1 Ground based technical photography conducted by Sandia Corp was extensive with specific requirements for coverage such as: air shock and surface ground motions, various other phenomena, structures, etc.

SHOT	LOCATION	CAMERA RANGE FROM GZ(ft)	# CAMERAS
Sugar	Tower	15,000	14
Sugar	Tower	15,000	19
Sugar	Tower	9,111	16
Sugar	Surface	8,000	3
Sugar	Surface	10,000	4
Sugar	Surface	5,000	7
Uncle	Tower	15,000	10
Uncle	Tower	15,000	16
Uncle	Tower	9,012	13
Uncle	Surface	14,020	2
Uncle	Surface	10,000	4
Uncle	Surface	4,775	5
Uncle	Surface	4,495	3
Uncle	Surface	5,000	4
Uncle	Surface	2,100	4

(Barr 1952: 1-12)

4.1a-2 The technical photography of 4.1a-1 was used to determine the dimensions of the cloud and column from time zero to +3 minutes. This was done with the aid of Fiducial targets that were placed between each camera and ground zero. A second objective, "to determine the times of disintegration, damage or movement of each of the structures", was not fulfilled because damage and movement was too slight to be seen on the film.(Miller 1952: v)

TUMBLER-SNAPPER

9.1 Eight groups of military personnel from the Army, Navy, and Air Force underwent training and supported AFSWP participants by taking photographs and motion pictures of the

detonation and AFSWP's projects. An additional 21 Army personnel provided photographic coverage for Desert Rock exercises on Charlie and Dog.(Ponton 1982b: 105, 107)

UPSHOT-KNOTHOLE

9.1 provided a centralized organization responsible for all technical motion picture and still photography required by DoD effects projects. On Encore and Grable, motion picture photography captured the effects of blast and thermal radiation on various test objects. The shock front itself was photographed on Annie, Dixie, Encore, Grable, and Climax. All zero time photography was done from individual photo stations, generally steel towers located at distances between 1,150 and 15,000 feet from IGZ. Encore had 193 cameras on 100 towers between 6' and 25' high. Grable used 94 cameras which were on 50' towers. Shot Annie, Dixie, and Climax were covered by only 4 cameras mounted in photo trailers. The photographic hazards during a nuclear test (dust, thermal and nuclear radiations, blast, and rapidly changing illumination) were overcome at distances from GZ greater than about 2,500'. At closer distances, results were unsatisfactory.(EG&G 1953b: 3, 11-2)

9.6 Dust presented the greatest difficulty encountered when photographing a nuclear test. To stabilize the soil Approximately 700,000 yd ^{2} of 2" thick sand-cement mat was laid at over 40 selected areas between 2,000' to 12,000' from IGZ for Encore and Grable. The pours ranged from about 400 to 63,000 yd ^{2}. The materials used were: about 63,000 tons of crushed and sieved sand from Frenchman Flat, 21,463 barrels of Portland cement, about 154,000 lb of calcium chloride as a curing agent, and 5,250,000 gal of water. For touch up prior to each shot, approximately 25,000 gal of sodium silicate was used with water. It was also used to stabilize the mounded-over portions of buried structures within the stabilization areas. The extremely low humidity (7-15%) presented numerous difficulties in the processing and curing of the cement; and different processes were tried. "Motion picture coverage was far better on this operation than on previous ones."(Duval 1953: 3, 15-6, 20-3)

9.7 evaluated the performance of several soil-stabilizing materials used in 9.6. Test panels of the materials were constructed, exposed, and observed; and observations of the stabilized areas in 9.6 were also made. Some construction guidelines were developed.(Shockley 1954: 3, 28-9)

TEAPOT

9.4 documented the evolution of atomic clouds during TEAPOT. Specific characteristics sought were: rate of rise, maximum height, vertical depth of mushroom, and dimensions and volume of stem. Photograhic coverage was taken up to 20 min after burst. A second objective was to "correlate the meteorological data with available cloud data on past operations as well as TEAPOT." Photographic and theodolite* data were collected on all shots.(Grossman 1955: 3) [*Footnote: A theodolite is a surveying instrument for measuring vertical nd horizontal angles with a rotating telescope.]

PLUMBBOB

9.1 The Lookout Mountain Laboratory Group from Hollywood, CA, staffed by the 1352nd Motion Picture Squadron with about two dozen participants provided support for the technical photography of the DoD programs and projects. A motion picture was produced. They provided documentation of the detonations for historical purposes as well as release to the

press through the Joint Office of Test Information (JOTI). It was possible to process, classify, and release coverage through the JOTI to the press within 2 hours of after each detonation. Approximately 5,000 still photographs were made.(Harris 1981b:143)

L: POST-SHOT SAMPLE COLLECTION and SURVEYS for RADIOACTIVITY, INCLUDES INDUCED RADIOACTIVITY

JANGLE

All of the following JANGLE projects were conducted on both Uncle and Sugar.

2.1d Monitor survey teams used a Radiac Training Set for making measurements of the radiation fields at 104 specific locations after Sugar, and at 83 after Uncle. Measurements were acquired at times >+1 hour with the instruments being held about 3 feet above the ground. An interesting observation: "Non-uniformities in the field were practically absent until the wind became sufficiently strong to shift the contamination, at which time there was a localization of contamination in ditches and behind obstructions". On January 25, 1952, surveys were made of the lips of the craters. (Johnson 1952:1-2, 10-11, 17-19)

2.4a Measurements of beta and gamma residual radiations were made postshot on Sugar and Uncle to determine:
1) energy of the beta radiation at early times postshot
2) the ratio of beta to gamma ionization
3) the gamma-ray energy of residual fission-products and its change with time. During various times postshot, measurements were made at about 50 stations along 3 radial lines from 1,000' to 12,000' from GZ with: different types of photographic film and about a dozen energy-dependent ionization chambers that were commercially constructed as small personnel dosimeter instruments. (Tochilin 1952: 1,5,25, 34-5, 74-6)

2.4c A truck containing a scintillation spectrometer was driven to contaminated locations of Sugar and Uncle between 2 hours and 4 days to obtain the gamma ray spectrum. Some data was obtained after Uncle. This was a cumbersome means of obtaining gamma spectrum. (Bernstein 1952: vii, 6)

2.5a-1 Samples of aerosol and fall-out were obtained from 46 stations located between 4,000 feet upwind and 50,000 feet downwind from the tests. Instruments used were: filter samplers; cascade impactors; conifuges; particle separators; electrostatic precipitators; Brookhaven and Tracerlab continuous air monitors and fall-out trays. Beta activity was measured as was the number and size of particles collected. Size decreased with distance from GZ. Studies were also made of: particle size versus radiation level, comparisons of aerosol and fall-out particle properties, and fractionation.(Robbines et. al. 1952: 2.5a-1 iii)

2.5a-2 was similar to 2.5a-1; but also included the design and development of: aerosol couplers, differential fall-out collectors, and fall-out trays that were used. Time distribution studies showed: "heavy initial concentrations transported by high altitude winds and followed by several secondary waves of material carried by surface witnds. Area distributions were

found to be determined by the extent of the base surge and wind profile." (Robbines et. al. 1952: 2.5a-2 xi)

2.5a-3 Trays were placed downwind 5 to 10 miles from GZ. Particle size, radioactivity and its decay, and chemical composition were determined. Particles as large as 500 microns fell as far as 10 miles from GZ. (Robbines et. al. 1952: 2.5a-3 v)

2.6a Remotely controlled "weasels" were developed and successfully used to obtain surface and core samples from around the lip and crater areas. Four weasels were used: 2 for surface sampling, capable of picking up ten samples of 2 in^3 ; and 2 with earth corers, capable of taking earth core samples 6" deep and 2" in diameter with 6 to 8 sampling points. The weasels had an ionization chamber probe to measure gamma rate in the area where samples were taken and to telemeter the information to "control", a tower about 1,830 meters from each crater. They also had television cameras to guide and observe the operations. Additional components of the weasel system were 2 mobile control stations on trucks with semi-portable 24' towers and a jeep equipped with a mobile control transmitter.(Forbes 1952a: ix, 1-23)

2.6c-1 and 2.6c-2 conducted "chemical analyses of surface soil samples, fallout samples, ground air filter samples, and high-air filter samples". Some soil samples were acquired by the Project 2.6a weasels. Samples showed "that the composition of residual fission products varies greatly with the place and mode of sampling". (Maxwell 1952b: Document Page)

2.6c-3 A rocket that towed a line with it and had a sampling head at its tip was used to obtain radioactive lip and crater samples. The sampling head was driven into the ground by its own impact. After sample acquisition, the rocket could be towed away form the high radioactive area. This rocket system was mounted on a truck and had a range of about 1100' with a probably impact area of approximately 75' in diameter. Sampling was done at D+2 on both craters, and an attempt was made to add dosimeters to the rockets on D+3 of Uncle.(Maxwell 1952a: vii, 1-6)

2.8 This project was conducted by the Bureau of Plant Industry, Soil and Agricultural Engineering of the US Department of Agriculture. It was an extension of projects 2.5a-1, 2.5a-2, and 2.5a-3 which were conducted by the Army Chemical Center, the US Naval Radiological Defense Laboratory, and the Army Medical Service Graduate School respectively. It used samples as described above for those projects. Among the activites undertaken were the determination of particle size distribution and chemistry of samples from various locations around the Sugar and Uncle tests as well as from fall out samples. A beta emitting element had a high uptake in different soils and had approximately a 50day half-life. "The element is thought to be strontium 89. The amount taken up from a soil low in calcium is of a magnitude that might constitute a hazard to agriculture."(Alexander 1952:vii)

<u>UPSHOT-KNOTHOLE</u>

2.2a Residual gamma radiation was measured at times varying from 1 hour to 10 days following 5 detonations at positions near GZ for air bursts and at ranges from 1000 yards to 3

miles from GZ for tower shots. Results from scintillation techniques and ionization chambers were correlated.(Bass 1955: 3,5)

4.7 Betas are always present in bomb contamination. (Brennan 1953:11-12) states: "—to date, it has not been possible to make a portable survey meter which will measure beta hazard". " – it has been the policy, in all field efforts since 1943, to measure radiation hazard by monitoring for gamma only". "The survey instruments, dosimeters, and film badges employed in the field are designed to measure only gamma rays having an energy greater than about 80 KV. Such a policy tacitly assumes that, in all cases, the accompanying unmeasured beta and soft gamma dose is negligible." "-- four separate theoretical approaches indicate that the beta hazed in a bomb contaminated area might be much greater than the associated gamma hazard."(ibid. 13) "—beta particles penetrate poorly and a chamber wall of any convenient thickness is apt to be opaque."(ibid. 15)

A 1944 paper by H. M. Parker* proposed that: "Since skin has an insensitive layer about 0.1mm or 10mg/cm^2, in thickness, why not construct ion chambers with walls of the same thickness?" [*Footnote: Parker, H. M., "Some Physical Aspects of the Effects of Beta Radiation on Tissue, AECD-2859.] Special thin-walled ion chambers were constructed for this project that measured the total skin hazard due to betas and gammas. Thick-walled ion chambers (like those in usage that did not measure the betas and only gammas above 80KV) were also used.

As soon as possible postshot, personnel went into the radiation field. The first measurements made at a spot were the free-air measurements with thick and thin walled chambers. This gave a general idea of the quantity of beta and soft radiation present. They then set up a 180 lb masonite phantom with film badges and dosimeters attached. Measurements were made on both the "naked" and "clothed" phantom with the thin walled chamber.(ibid. 16-20) The results were: "—although there is, indeed, an increase in radiation hazard at points near the ground, the very large beta dose to be expected from theory does not actually occur in the field". (ibid. 3)

<u>TEAPOT</u>

2.3a provided information on the nature of the gamma radiation induced in soils by neutron radiation from a detonation. Within the first day after Wasp, Turk, and ESS, samples "were simply dug from the earth" in the vicinity of GZ; and their gamma-ray spectra were then analyzed. On Hornet, 10 soil samples were exposed, one soil sample was from the NTS, the other 9 were "typical representatives of sands, loams.and clays", supplied by the Dept. of Agriculture from within the US continental limits, Hawaii, and Puerto Rico. (Johnson 1958: 5, 11,23-4)

2.3b Nine days after ESS, a six-wheel-drive truck that was equipped with a scintillation counter instrumentation that could obtain data in any direction was used to collect data regarding gamma-ray activity from direct unscattered radiation and excess radiation. The direct unscattered radiation (about 80% of the roentgen effectiveness) was readily recognized from its unique directional distribution. The excess radiation, over the direct, was assumed to be caused by scattering.(Mather 1955: 4, 13-4, 18)

2.4 Activities were in 3 areas: 1) Documenting ESS's residual radiation fields; 2) Recording decay rates of neutron-induced fields for Wasp and Wasp'; and 3) Measuring residual fields from Moth and Tesla. Ion chambers and scintillation counters were deployed, with 25 on ESS and 3 on the other shots.(Graham 1959b:4, 15-7)

2.5.1 The US AEC conducted this multifaceted project whose primary objective was to obtain data to construct contours for radiation dose rate levels down to and including 1 r/hr at H+1 hour for ESS. In so doing, they obtained radiation intensity information on:1) The base surge; 2) Fallout areas, areas contaminated by the base surge, and the crater lip; 3) When the activity arrived where; 4) Depth of the activity in the crater and on the lip; and 5) Correlation between radiation intensity measured in air and on the ground. (Schumchyk 1958: 5)

Inovative instrumentation was used in the field activities:
- 20 Intermittent Fallout Collectors (IFCs) were placed at various distances and collected samples at timed intervals from the base surge and cloud fallout.
- 2 Aerosol Samplers collected air samples on filter papers at preset times.
- An aerial survey instrument was operated by lowering a survey probe through the side door of a helicopter until the probe touched the ground with the detector 3' above the ground where a measurement was taken. Measurements were also taken at different altitudes. The probe and detector were on a cable that was wound on a hand-operated reel mounted inside the helicopter.
- Gamma survey meters were used by the recovery parties to obtain ground measurements of radiation intensity.
- A core sampler was designed, tested, fabricated, and successfully used to collect samples from the lip outward as well as down into the crater.

(ibid. 19-23, 32, 81-2,123)

2.5.2 Fallout was collected at locations down wind of ESS out to 18,000 yards. Numerous total collectors consisting of 8 quart buckets 8" deep were placed on poles about 6' above ground; 4 "time total collectors" were used that were covered by a movable belt which opened and closed at set times; gamma time-intensity recorders were also used. Radiac equipment was used for field measurements by personnel and numerous film badges were placed in the field.(Stetson 1958: 18-20)

<u>PLUMBBOB</u>

2.1 investigated the radioactivity induced in soils by the neutron flux produced by the new tactical "neutron bomb" weapons. Three types of American soils were investigated: 1) Fine sandy loam from Collier County, FL with high silicon content and low mineral-constituents; 2) Chester loam from Montgomery County, MD, with a strong aluminum concentration and a fairly high manganese content; and 3) NTS, Area 7, soil with a large sodium composition, significant aluminum and manganese content as was present at the PLUMBBOB detonations. A cubic yard of each of these 3 materials and some addition samples with water content variations (natural, 50% and 100% saturation) were buried with their top surfaces at ground level and exposed on: Franklin, Lassen and Priscilla (at 10 ranges along 1 azimuth); Wilson (at 5 ranges on 2 azimuths); and Owens (at 4 ranges along 3 azimuths).

Postshot, the soil samples were automatically ejected from their buried locations and towed out of the contaminated area on a 1,000 yard steel cable. The radioactive samples were then reinserted into non-radioactive cubic yard samples of their own soil type and monitored for dose rate as radioactivity was induced in the non active soil.(DASA 1960e: 15, 20-2)

2.2 investigated the radioactivity produced by the interaction of neutrons from a nuclear device with soil. Primary participation was on Owens and secondary participation was on Wilson, Hood, and LaPlace, all balloon shots with a minimal amount of shielding around each device (minimal shielding is representative of a weapon). Fifteen elements* that represented "significant elements in the soils of the world" were exposed to the neutron flux from Wilson and Owens.[* aluminum, copper, titanium, calcium, magnesium, iodine, chlorine, nickel, silicon, manganese, potassium, sodium, arsenic, chromium, and iron] Gold and sulfur were also used in order to measure the thermal and fast neutron fluxes.

The samples were placed in special aluminum containers 10 ¾" OD and 30 3/8" long that contained 4 trays on which to place the samples. A great deal of work went into preparing the samples and determining where they should be located. Not all elements were located at all ranges. On Owens there were 12 ranges used with between 1 and 3 containers at each range; on Wilson 2 ranges with 3 containers each; and LaPlace 1 container. Recovery of containers was mostly by personnel on the ground, but helicopter recovery was used for some containers on Wilson. There was a mobile laboratory trailer in the field for rapid analysis of short-lived isotopes. On Hood, the gamma radiation from induced radioactivity in an Army M-48 tank was observed.(DASA 1959: 11, 17-26)

2.11 LaPlace was expected to produce a high neutron flux per unit of yield, but it was deleted from the schedule. Owens was used but not with satisfaction; then LaPlace was placed back on the schedule and used by this project.

The instrumentation used during the test consisted of: neutron detectors, neutron versus depth detectors, three types of film badges, and chemical dosimeters. Twenty-six stations were placed on a line extending from GZ to 3,000 yards on an azimuth of 225°. Upon first entry into the field at about H+1hr, at 450 yards ground range, a "specially prepared mounting jig" was installed in the field on which monitoring meters were mounted. The decay of the induced field was monitored starting at H+1hr and continuing until about H+36 hrs. A variety of measurements of induced gamma activities were made. (Chiment 1959: 11,14-7)

M: LONG RANGE DETECTION

Ma. Radchem

BUSTER

7.1 The first radiation chemistry method for long range detection determined:

- the initial cloud dimensions;
- the movement of the cloud within a few hundred miles of the site;

- the cloud width and the concentration of debris, primarily over the eastern part of the US; and
- the concentration of fallout at the surface.

This project used aircraft and filters for tracking the cloud and specialized in meteorological analyses and predictions. On occasion additional ground samples were obtained. (Allen 1952:1, 5-9)

7.3 The Air Force Office for Atomic Testing (AFOAT) conducted radiochemical analyses of the radioactive debris samples that were collected by aircraft with filters at locations close-in and out to about 1200 miles from the detonation point. Radioactive particles and decay processes were identified in the samples that were collected. (Singlevich 1952: v, 1-3)

UPSHOT-KNOTHOLE
7.5 On all 11 tests, the Air Force conducted operations for the collection of bomb debris and analysis like that conducted on all previous NPG operations.(Ponton 1982a: 118-9)

Mb. Seismic
BUSTER
7.5 Measurements were made of seismic waves generated by detonations. At less than 20 km from GZ, an assortment of 28 accelerometers, displacement meters, and tiltmeters were deployed. Between Reno, NV and Prescott, AZ, 74 displacement meters were fielded; and 26 velocity meters and a long-period displacement meter were placed between 900 and 2700 km. In addition, data from existing seismic observatories were also used in the analyses. (Crocker 1952: ix, 1-4)

TUMBLER-SNAPPER
7.4 A continuation of BUSTER 7.5. Results confirmed that: "About 5 percent of the energy which entered the ground as seismic waves reached the sub-basement rock, hence only this amount contributed to ground motion at regional seismograph stations." This project placed considerable emphasis on the close-in measurements that included acceleration and displacement. Measurements were made at and near GZ and near the NPG. Five stations were set up in Yucca Flat and 4 in Frenchman Flat.(Carder 1953: 3, 7-14)

UPSHOT-KNOTHOLE
7.4 continued seismic work of previous operations with seismographs located at: Mercury, Tucson, AZ 372 mi; Encampment ,WY 498 mi, Laramie, WY 546 mi; Douglas, WY 582 mi; Hungry Horse, MT, 702 mi; Lead. SD 708 mi; Fort Sill OK 882 mi; Equality, AL 1488 mi; Fairbanks, AK 1998 mi. Note that these distances did not extend as far as those being used at this time for sound detection. Two seismographs were installed in drifts of a gold mine in Lead, SD, one at 300' and the other at 5,000' below the surface. This was done to examine the signal-to-noise ratios as instruments were removed from the earth's surface. Also, ZIPAGRAM – communication of seismic data from a recording station to a central analysis point – was successfully tested.(Crocker 1955: 3, 13, 16)

Mc. Sound

BUSTER

7.6 The feasibility of low-frequency sound detection was explored from the detonations on BUSTER. They were made at 10 locations in several directions and distances. Baker, Charlie, and Easy were detected at 2200 miles and Dog was detected at 2600 miles, in Oahu. (Olmsted 1952a: viii, 1-6)

TUMBLER-SNAPPER

7.2 A continuation of BUSTER 7.6 with promising results in terms of distances where sound was detected from shots Baker through How. Seven stations were used: Ft. Lewis, WA; Pyote AFB, TX; Breckinridge, KY; Washington, D.C.; Belmar, NJ; Fairbanks, AK; and Oahu, HI.(Olmsted 1952b: 11-30)

UPSHOT-KNOTHOLE

7.3 continued work on sound detection of previous operations. Fifteen stations, 4 of them in other countries, were used: Los Angeles, CA 380km; San Diego, CA 475km; Dateland, AZ 505km; Gila Bend, AZ 530km; Ft. Lewis, WA 1230km; Pyote AFB, TX 1350km; Barksdale AFB, LA 2080km; Washington, D.C. 3400km; Belmar, NJ 3585km; Fairbanks, AK 3710km; Oahu, HI 4375km; Thule, Greenland 5000km; Hachinohe, Japan 8300km; Hanau, Germany 8900km; and Kyoto, Japan 9100km. The maximum distance at which positive detection occurred was 9100 km at Koyoto for Climax.(Olmsted 1954: 3, 21, 27)

Md. Electromagnetic (EM)

TUMBLER-SNAPPER

7.1a represented the first coordinated effort to observe and record the illusive EM pulses. The rise time of the pulse is very rapid, microseconds; and it "starts with the emission of the prompt gamma rays, before the case is shattered". Stations were set up at: the test site in Yucca Flat; Stanford University; Boulder, CO, Alamagordo, NM; Robins, GA; Sterling, VA; McDill, FL; Ramey, Puerto Rico; Maynard Mass.; Kindley, Bermuda; and Camp King Germany. Various antenna, receivers and recorders were assembled from standard radio equipment and installed at the stations. The station in Yucca Flat was constructed with special equipment within a truck which could move for the different shots. Recordings were made on shots Charlie through How.(Oleson 1953: 3, 11-16)

UPSHOT-KNOTHOLE

6.7 consisted of two parts. One was the detection and measurement of EM signals at line-of-sight ranges. The data obtained indicated "a lack of consistency from shot to shot and no clear correlation with yield". The second part of this project was the detection of EM signals prior to the nuclear detonation itself that would be generated from the detonation of HE. It was found that these pre-nuclear signals were below the threshold of detection. The instrumentation was simple consisting of antenna(s) and small scale electronic equipment and was fielded on all shots of the operation.(Signal Corps Engineering Lab 1956: 3, 12-4) .

7.1 continued work begun on TUMBLER-SNAPPER 7.1a and was conducted on all UPSHOT-KNOTHOLE tests.(Ponton 1982a: 118)

TEAPOT

6.3 tested the feasibility of a tactical detonation locator system designed to locate GZ by detection and analysis of the EM signal. It was also desired that the system furnish yield and HOB. Detection stations were located 60 and 200 miles from the test site, and all shots but the last were used. Results for locating GZ appeared promising, but the data provided no conclusive evidence regarding yield or HOB capabilities. (Miller 1957: 3)

HARDTACK II

6.15 Equipment was designed to locate "friendly nuclear detonations" -- the approximate location and time were known in advance – by their EM signal. The instruments were located on the outskirts of Boulder City, NV, approximately 100 miles from NTS. Participation was on 10 of the weapons development tests, Mora thru Wrangell, with 4 tests having yields greater than 1 kt and 6 having yields of less than a kt.(Cantor 1960: 5,9) It was also conducted on 4 safety tests: Mars, Hidalgo, Neptune, and Vesta with yields between 13 and 115 tons. (Ponton 1982d: 191, 195, 198, 201) This is the only NWE project to be conducted on a safety test during HARDTACK II. The report concluded that the equipment adequately recorded "friendly nuclear detonations" in the kiloton range.(Cantor 1960: 5)

Me. Light

BUSTER

7.2 Stations that were set up at Las Vegas, NV, Flagstaff, AZ, and Albuquerque, NM to detect light from the detonations. The stations were also equipped to obtain time to minimum light intensity (like a bhangmeter measurement) and to obtain data on the attenuation of light over paths of hundreds of miles. (Colson 1952: xi, 13-16)

SNAPPER

7.1b EG&G and the Air Force manned 5 teams that used equipment designed to detect small changes of light on the horizon. The teams were located between 268 and 1020 miles from the points of detonation. Results indicated that .. " it is not considered feasible to detect, much less to determine yield from, nominal size nuclear detonations at distances much in excess of approximately 430 miles from ground station stations and then only during favorable weather".(EG&G 1953a: 3)

PART II. CIVIL DEFENSE (CD) NUCLEAR WEAPONS EFFECTS (NEW) PROGRAMS AND PROJECTS ON NTS OPERATIONS 1951-1958

CHAPTER II-1. LISTS AND TABLES OF CD NWE PROGRAMS AND PROJECTS

Introduction

This Part II parallels Part I. However, the descriptions regarding the organization of projects and background material that were presented in the Introduction to Part I Chapter 1 are not repeated here.

This chapter has four sections after this Introduction, one section for each of the four NTS atmospheric test operations on which the CD had a test group and conducted their projects. These four sections list the programs and projects conducted; the responsible organization(s); and the WT reference report number. Following the list, a table is given indicating the tests on which each project was conducted.

During the four operations on which CD groups conducted projects, the following sets of numbers were assigned (FCDA, Federal Civil Defense Agency and OCDM*, Office of Civil Defense for the numbering of their programs:
[*Footnote: Prior to July 1, 1958, the civil part of OCDM was known as the Federal Civil Defense Agency (FCDA) and the defense part of OCDM was known as the Office of Defense Mobilization (ODM). After July 1, 1958, FCDA and ODM were combined into OCDM.]

OPERATION	FCDA	OCDM
UPSHOT-KNOTHOLE	20-29	
TEAPOT	30-39	
PLUMBBOB	30-39	
HARDTACK II	30-39	70-71

Table II-1 lists the CD programs on each NTS operation and cites how many projects were in each program. A total of 158 civil defense projects were conducted by the CD test groups during the 4 NTS operations between 1953 and 1958. The CD program numbers were not as consistent with respect to technical content from operation to operation as were the DoD programs.

Table II-1. Civil Defense NWE Programs on Atmospheric Tests at NTS.

OPERATION	PROGRAM	# Projects
UPSHOT-KNOTHOLE	21) Effects Studies (on Shelters)	3
	22) Radiological Defense and Radiation Effects	4
	23) Biomedical Experiments	17
11 Tests	24) Structures	3
	26) Civilian Vehicle Tests	2
	27) Fall-Out Studies in Near Areas	2
	28) Radiation-Telemetering Systems	1
	29) Dosimetry and Radiation Measurements	4
	Total	**36**

TEAPOT 14 Tests	30) Evaluation and Documentation of Radiological Contamination	3
	31) Response of Residential, Commercial, and Industrial Buildings, and Materials to Nuclear Effects	5
	32) Exposure of Foods and Food Stuffs to Nuclear Explosions	6
	33) Biological and Medical Investigations	3
	34) Shelters for Civil Populations	4
	35) Utilities, Services, and Associated Equipment Exposed to Nuclear Explosion	5
	36) Mobile Housing and Emergency Vehicles	2
	37) Fallout Studies	4
	38) Civil Defense Radiological Effects Studies	5
	39) Program Instrumentation and Photography	10
	Total	**47**
PLUMBBOB 24 Tests	30) Shelters for Civilian Population	10
	31) Structures, Equipment, Devices, and Components	5
	32) Radiological Countermeasures	4
	33) Biological Assessment of Blast Effects	6
	34) Physical Response to Blast Loadings	5
	35) Radiological Defense Techniques	4
	36) Radiological Defense Operations	5
	37) Radio-Ecological Aspects of Nuclear Fallout	6
	38) Effects of Radioactive Fallout on Foodstuffs	4
	39) Instrumentation and Dosimetry	13
	Total	**62**
HARDTACK II 37 Tests	34) Nuclear Effects, AEC Test Structures	3
	37) Further Evaluation of Tower and Balloon Shot Fallout Patterns	1
	39) Radiation for Human Exposures	3
	70) Office of Civil Defense Mobilization Test Group Projects	6
	Total	**13**
	TOTAL # of Projects	**158**

In the following, the 158 civil defense projects conducted are listed by operation. They are listed for each operation by increasing program number, then by increasing project number for that program number, with the following format:

Program#.Project # Title – Organization(s). (WT-#)

The types of organizations that conducted NWE projects and the approximate percentage of the 158 projects that they conducted were:

FCDA and OCDM were themselves the major participants, ~ 39%.

AEC, ~ 20%
Primarily by its Divisions of Biology and Medicine and Health and Safety Laboratory, the New York Operations Office and by AEC sponsored laboratories: Los Alamos, Sandia, Oak Ridge, and Brookhaven.

Other Civilian Government Laboratories or organizations, ~5%
Lovelace Foundation; House and Home Finance Agency; Public Building Service (PBS); General Services Administration (GSA); National Bureau of Standards (NBS); Civil Aeronautics Administration; Food and Drug Administration; and Surgeon General.

Military, ~16%
Air Force School of Aviation Medicine; Army Ballistics Research Laboratories (BRL); Defense Air Transport Administration; Naval Radiological Defense Laboratory (NRDL); and Naval Medical Research Institute. Although not directly responsible for specific projects, AFSWP lent many a helping hand.

State of California Civil Defense, ~0.5%

Universities, ~9.5%
Armour Research Foundation; California at Los Angeles, Harvard, Rochester, and Tennessee.

Private organizations, ~10%
American Gas Association; American Machine and Foundary Company; Ammann and Whitney; Eastman; Holms and Narver; EG&G, Liquified Petroleum Gas Association; Radio, Electronics, Television Manufacturers; Structural and Clay Products Research Foundation; and Vitro Corporation of America.

The Weapons Test (WT) report number for the project is given next. Prior to the issuance of a WT report, an Interim Technical Report (ITR) would often be written to make results readily available to others. Usually, these ITR reports did not contain the level of analysis or completeness of the final WT report, and in a few cases, a final report was not written. There are more ITR reports listed here for the civil defense reports than was the case for the DoD reports.

Post shot reports or descriptions of 13 of the CD projects, most of them on PLUMBBOB, have not been located by the author. For these projects, NA (not available) is indicated in the following tables. Prior to each operation, FCDA issued summaries of the projects it planned to undertake. These summaries were usually used to develop the descriptions

provided here (which are cast in the past future perfect tense) of the 13 undocumented projects. None of these 13 projects represented major FCDA efforts.

CD NWE PROGRAMS AND PROJECTS ON UPSHOT-KNOTHOLE: 3/17/53 – 6/04/53

Program 21) Effects Studies (On Shelters)

21.1 Effects of an Atomic Explosion on Underground and Basement Types of Home Shelters – AEC; FCDA. (WT-801)
21.2 Effects of an Atomic Explosion on Two Typical Two-Story-and-Basement Wood-Frame Houses – FCDA. (WT-792)
21.3 Air-Zero locators – FCDA.

Program 22) Radiological Defense (Radef) and Radiation Effects

22.1 Evaluation of Training Program for Radiological Defense Purposes – FCDA. (WT-808)
22.2 Various Aspects of Nuclear Radiation Measurements for Civil Defense Radiological Defense Purposes – FCDA. (WT-805)
22.3 Radiological Hazards in Civil Defense – FCDA. -- NA
22.4 Exposure of Drugs to Nuclear Explosions – FCDA. (WT-810)

Program 23) Biomedical Experiments

23.1 Biological Effectiveness of Ionizing Radiation Within Shelters – Naval Radiological Defense Laboratory. (WT-793)
23.2 Bacteriological Studies on Animals Exposed to Neutron Radiation – Naval Radiological Defense Laboratory. (WT-794)
23.3 Long-Term Studies of Dogs Exposed to Primarily Neutron Irradiation in Shelters – Naval Radiological Defense Laboratory.
23.4 to 23.14 & 23.16 Genetic Effects of Fast Neutrons from Nuclear Radiations – AEC. (WT-820)
23.15 Effects of Overpressures in Group Shelters on Animals and Dummies – Lovelace Foundation, WT-798)
23.17 Neutron-Flux Measurements in AEC Communal Shelters and Lead Hemispheres -- Naval Radiological Defense Laboratory. (WT-795)

Program 24) Structures

24.1 Evaluation of Communal Shelters – AEC. -- NA
24.2 Physical Measurements of Gamma and Neutron Radiation in Shelter and Instrument Evaluation – AEC. (WT-789)
24.3 AEC Shelter Instrumentation – Vitro Corporation of America. (WT-790)

Program 26) Civilian-Vehicle Tests

26.1 & 26.2 Physical, Mechanical, and Irradiation Evaluation of Civilian Vehicles Exposed to Atomic Attack – AEC; FCDA.

Program 27) Fall-Out Studies in Near Areas

27.1 Distribution and Characterization of Fallout at Distances Greater Than 10 Miles from Ground Zero, March and April 1953 – University of California, Los Angeles. (WT-811)
27.2 Environmental and Biological Fate of Fallout from Nuclear Detonations in Areas Adjacent to the Nevada Proving Grounds – University of California, Los Angeles. (WT- 812)

Program 28) Radiation-Telemetering Systems

28.1 Test of a Radiation Telemetering System – AEC. (WT-796)

Program 29) Dosimetry and Radiation Measurements

29.1 Comparison and Evaluation of Dosimetry Methods Applicable to Gamma Radiation – University of California, Los Angeles. (WT-802)
29.2 Fast Neutron Effects on Semi-Conductors – University of California, Los Angeles. (WT-803)
29.3 Evaluation of Dosimetry for Civil Effects Programs – AEC.
29.4 Effective Energy of Residual Gamma Radiation – University of Rochester. (WT-814)

Table II-2. CD NWE Projects Conducted on UPSHOT-KNOTHOLE Tests.
(Ponton et.al 1982a:132)

TEST → / PROJECT	ANNIE*	NANCY	RUTH	DIXIE	RAY	BADGER	SIMON	ENCORE	HARRY	GRABLE	CLIMAX
Program 21) Effects Studies (On Shelters)											
21.1	X										
21.2	X										
21.3	X							X			
Program 22) FCDA Radiological Defense and Radiation Effects											
22.1							X				
22.2						X	X	X			
22.3 NA 2 shots planned											
22.4							X		X		
Program 23) Biomedical Experiments											
23.1	X		X	X				X	X		X
23.2	X		X	X				X	X		
23.3	X		X	X				X	X		
23.4	X									X	
23.5	X									X	
23.6	X									X	
23.7	X									X	
23.8	X							X		X	
23.9	X									X	
23.10	X										
23.11	X										
23.12	X							X		X	
23.13	X										
23.14	X							X			
23.15	X							X			X
23.16	X									X	
23.17	X		X	X				X	X	X	X
Program 24) AEC Shelter Structures											
24.1 NA 4 shots planned											
24.2	X					X		X	X	X	X
24.3	X								X		
Program 26) Civilian Vehicle Tests											
26.1	X		X	X				X		X	
26.2	X		X	X				X			
Program 27) Fallout Studies in Near Areas											
27.1		X	X	X		X	X				
27.2		X	X			X	X				

Program 28) Radiation Telemetering System											
28.1	X	X	X	X		X	X				
Program 29) Dosimetery and Radiation Measurements											
29.1				X	X	X	X	X	X	X	X
29.2	X								X		X
29.3	X	X	X	X	X		X				
29.4	X	X					X				

* The projects conducted during Annie were considered as Operation DOORSTEP.
NA = FCDA report or information - Not Available.

CD NWE PROGRAMS AND PROJECTS ON TEAPOT: 2/18/55 – 5/15/55

(Paterson 1955: 27-73; USAEC 1969:37-8)

Program 30) Evaluation and Documentation of Radiological Contamination

30.1 Measurement of Off-Site Fallout by Automatic Monitoring Stations – AEC, New York Operations Office. (WT-1186)

30.2 Utilization of Telemetering Techniques in Evaluating Residual Radioactive Contamination – AEC Division of Biology and Medicine. (WT-1182)

30.3 Measurement of Beta and Gamma Ray Characteristics of Shot Debris and Fallout of Nuclear Weapons – AEC New York. (ITR-1185)

Program 31) Response of Residential, Commercial, and Industrial Structures and Materials to Nuclear Effects (#143768)

31.1 Damage to Conventional and Special Types of Residences Exposed to Nuclear Effects – House and Home Finance Agency; FCDA. (WT-1194)

31.2 Damage to Commercial and Industrial Buildings to Nuclear Effects – FCDA. (WT-1189)

31.4 Comparison of Responses of Structural Slabs to Static and Atomic Blast Loadings – Public Building Service, General Services Administration; FCDA. (ITR-1195)

31.5 Thermal Ignition and Response of Materials – FCDA. (WT-1198)

31.6 Methods for Determining Yield and Location of Nuclear Explosions – FCDA; AEC. (ITR-1196)

Program 32) Exposure of Foods and Foodstuffs to Nuclear Explosions, Summary – WT-1222.

32.1 Effects of Nuclear Explosions on Bulk Food Staples – FCDA; AEC. (WT-1163)

32.2 Effects of Nuclear Explosions on Canned Foods – FCDA; AEC. (WT-1212)

32.2a Effects of Nuclear Explosions on Commercially Packaged Beverages – FCDA; AEC. (WT-1213)

32.3 Effects of Nuclear Explosions on Meat and Meat Products – FCDA; AEC. (WT-1216)

32.4 Effects of Nuclear Explosions on Semi-Perishable Foods and Food Packaging – FCDA; AEC. (WT- 1214)

32.5 Exposure of Foods to Nuclear Explosions: Effects on Frozen Foods – FCDA; AEC. (WT-1215)

Program 33) Biological and Medical Investigations

33.1 The Biological Effects of Pressure Phenomena Occuring Inside Protective Shelters Following a Nuclear Detonation – AEC Division of Biology and Medicine; Lovelace Foundation. (WT-1179)

33.2 The Effects of Noise in Blast Resistant Shelters – FCDA; AEC Division of Biology and Medicine; Sandia Laboratory. (WT-1180)

33.4 Distribution and Density of Missiles From Nuclear Explosions – AEC Division of Biology and Medicine; FCDA; Lovelace Foundation. (WT-1168 & WT-1217)

Program 34) Shelters For Civil Populations

34.1 & 34.3 Effects of An Atomic Explosion on Group- and Family-Type Personnel Shelters – FCDA. (WT-1161)

34.1 & 34.3 Evaluation of Various Types of Personnel Shelters Exposed to an Atomic Explosion – FCDA. (WT-1218)

34.2 Effects of a Non-Ideal Shock Wave on Blast Loading of a Structure – FCDA. (WT-1162)

34.4 Nuclear Effects on Machine Tools – Sandia Laboratory(WT-1184)

Program 35) Utilities, Services, and Associated Equipment Exposed to Nuclear Explosion

35.1 Effects of Atomic Weapons on Electrical Utilities – FCDA; AEC. (WT-1173)

35.2 The Effects of a Nuclear Explosion on Commercial Communications Equipment – Radio, Electronics, Television Manufacturers; FCDA. (ITR-1193)

35.4a The Effects of a Nuclear Explosion on Typical Liquefied Petroleum Gas (LPG) Installations and Facilities – Liquefied Petroleum Gas Association; FCDA. (WT-1175)

35.4b Natural and Manufactured Gas – American Gas Association; FCDA. (WT-1176)

35.5 The Effect of a Nuclear Explosion on Records and Record Storage Equipment – FCDA; AEC. (WT-1191)

Program 36) Mobile Housing and Emergency Vehicles

36.1 & 36.2 Exposure of Mobile Homes and Emergency Vehicles to Nuclear Explosions – FCDA. (WT-1181).

Program 37) Fallout Studies

37.1 Factors Influencing the Biological Fate and Persistence of Radioactive Fall-Out – AEC; University of California, Los Angeles. (WT-1177)

37.2 Distribution and Characteristics of Fallout and Airborne Activity from 10 to 160 Miles from Ground Zero, Spring 1955 – Civil Effects Test Group. (WT-1178)

37.2a Beta Skin-Dose Measurements by Specially Designed Film-Pack Dosimeters – AEC; University of California, Los Angeles. (WT-1178A)

37.3 Evaluation of the Acute Inhalation Hazard From Radioactive Fall-Out Materials by Analysis of Results From Field Operations and Controlled Inhalation Studies in the Laboratory – University of California at Los Angeles School of Medicine Atomic Energy Project. (WT-1172) NA

Program 38) Civil Defense Radiological Effects Studies

38.1 Civil Defense Monitoring Techniques – FCDA. (WT-1164)

38.2 Indoctrination and Training of Radiological Defense Personnel – FCDA. (WT-1165)

38.3 Evaluation of Civil Defense Radiological Defense Instruments – FCDA. (WT-1190)

38.4 Comparative Intensity of Gamma Radiation Under Area Contamination Conditions – FCDA. NA

38.5 Off-Site Radiological Defense Training Exercise -- State of California, Office of Civil Defense Division of Radiological Safety Services; FCDA. (WT-1183)

Program 39) Program Instrumentation and Photography

39.1 Gamma and Neutron Radiation Measurements – AEC Division of Biology and Medicine; FCDA; EG&G. (WT-1174)
39.2 Static and Dynamic Overpressure Measurements -- AEC Division of Biology and Medicine; FCDA; Sandia Laboratory. (ITR-1192)
39.3 Thermal Radiation Measurement – AEC Division of Biology and Medicine; FCDA; EG&G. (WT-1187)
39.4a Technical Photography - Documentary – AEC Division of Biology and Medicine; Los Alamos. (WT-1169)
39.4b Technical Photography (High Speed – Blast Biology) -- AEC; FCDA; Lovelace Foundation. (WT-1197)
39.4c Technical Photography, High Speed, Physical Phenomena (Structural Response) – FCDA; EG&G. (ITR-1188)
39.5 Measurements and Permanent Recording of Fast Neutrons by Effects on Semi-conductors – AEC Division of Biology and Medicine; Los Alamos; University of California, Los Angeles. (WT-1170)
39.6 Measurement of Initial Residual Radiation by Chemical Methods -- University of California at Los Angeles School of Medicine Atomic Energy Project. (ITR-1171)
39.7 Pt. 1 Physical Measurement of Neutron and Gamma Radiation Dose and Correlation of Dose With Biological Effect – LASL. (ITR-1167)
39.7 Pt. 2 Ionization Chamber Dose Measurements in Lead Hemispheres - LASL. (WT-1228) NA

Table II-3. CD NWE PROJECTS CONDUCTED ON TEAPOT TESTS
(Ponton et.al 1981b:120)

Test → / PROJECT	WASP	MOTH	TESLA	TURK	HORNET	BEE	ESS	APPLE1	WASP'	HA	POST	MET	APPLE2*	ZUCCHINI
Program 30) Evaluation and Documentation of Radiological Contamination														
30.1	X	X	X	X	X	X	X	X	X		X	X		X
30.2	X	X	X	X	X	X	X	X	X		X	X	X	X
30.3		X	X	X	X	X	X	X	X		X	X		
Program 31) Response of Residential, Commercial, Industrial Structures and Materials to Nuclear Effects														
31.1													X	
31.2													X	
31.4													X	
31.5													X	
31.6						X		X					X	
Program 32) Exposure of Foodstuffs to Nuclear Explosions														
32.1								X					X	
32.2 & 32.2a													X	
32.3													X	
32.4													X	
32.5													X	
Program 33) Biological and Medical Investigation														
33.1								X					X	
33.2								X					X	
33.4								X					X	
Program 34) Shelters for Civilian Populations														
34.1a													X	
34.1b								X					X	
34.2				X										
34.3								X					X	
34.4													X	
Program 35) Utilities, Services, and Associated Equipment Exposed to Nuclear Explosions														
35.1													X	
35.2													X	
35.4a													X	
35.4b													X	
35.5													X	

Program 36) Mobile Housing and Emergency Vehicles														
36.1													X	
36.2													X	
Program 37) Fallout Studies														
37.1				X		X	X	X				X	X	
37.2				X		X	X	X				X	X	
37.2a													X	
37.3 NA														
Program 38) Civil Defense Radiological Effects Studies														
38.1								X					X	
38.2													X	
38.3													X	
38.4 NA														
38.5													X	
Program 39) Program Instrumentation and Photography														
39.1	X	X	X		X	X	X	X	X			X	X	
39.2				X				X					X	
39.3													X	
39.4a	X	X	X	X	X			X	X				X	
39.4b								X					X	
39.4c													X	
39.5						X	X	X		X				
39.6	X	X			X						X	X		
39.7 Pt. 1	X	X			X	X			X					
39.7 Pt. 2 NA														

* The projects conducted during Apple 2 were considered as Operation CUE.
NA = FCDA report or information - Not Available.

CD NWE PROGRAMS AND PROJECTS ON PLUMBBOB: 9/15/57 – 10/7/57

(Corsbie 1957; USAEC 1969: 43-4; Jackson 1993)

Program 30) Shelters for Civil Population

30.1 Reinforced-Concrete Dome Mass Shelters – American Machine and Foundry Company. (ITR-1524)
30.2 Response of Dual Purpose Reinforced Concrete Mass Shelter – Ammann and Whitney. (WT-1449)
30.3 Evaluation of FCDA Family Shelter Mark I, for Protection Against Nuclear Weapons – FCDA. (ITR-1450)
30.4 Response of Protective Vaults to Blast Loading – Ammann and Whitney. (WT-1451)
30.5 Instrumentation of Structures for Airblast and Ground Shock Effects – Army Ballistic Research Laboratories. (WT-1452)
30.5a Dome Structure Response Instrumentation – Armour Research Foundation. (ITR 1525)
30.5b Instrumentation of French Underground Shelters – Army Ballistics Research Laboratories. (WT-1535).
30.5c Instrumentation for a German Shelter – Army Ballistics Research Laboratories. (WT-1536)
30.6 Structural Test - French Shelters – Aaman and Whitney. (WT-1453)
30.7 Structural Test - German Shelters – Amman and Whitney. (WT-1454)

Program 31) Structures, Equipment, Devices and Components

31.1 Thermal-Activated Air Zero Locators – FCDA; National Bureau of Standards; Eastman. (WT 1456)
31.2 Effects on Reinforced-Masonry Construction – Structural and Clay Products Research Foundation. (WT-1457) NA
31.3 Nuclear Effects on Civil Air Transport – Civil Aeronautics Administration; Defense Air Transport Administration. (WT-1458) NA
31.4 Behavior of Doors Under Blast Loadings – FCDA. (ITR-1459)
31.5 Test and Evaluation of Antiblast Valves for Protective Ventilating Systems – FCDA. (ITR-1460)

Program 32) Radiological Countermeasures

32.1 Attenuation Factors – Protection Against Fallout Radiation in a Simple Structure -- Shielding and Decontamination – AEC Health and Safety Laboratory, NY Operations Office. (WT-1462)
32.2 Field Use and Development of Aerial Radiological Monitoring System -- AEC Health and Safety Laboratory, NY Operations Office. (WT-1463) NA
32.3 Evaluation of Countermeasure System Components and Operational Procedures – Naval Radiological Defense Laboratory. (WT-1464)
32.4 Fallout Studies and Assessment of Radiological Phenomena – U.S. Naval Radiological Defense Laboratory. (ITR-1465)

Program 33) Biological Assessment of Blast Effects

33.1 Blast Biology – A Study of the Primary and Tertiary Effects of Blast in Open Underground Protective Shelters – Lovelace Foundation. (WT-1467)
33.2 Secondary Missiles Generated by Nuclear-Produced Blast Waves – Lovelace Foundation. (WT-1468)
33.3 Tertiary Effects of Blast–Displacement – Lovelace Foundation. (WT-1469)
33.4 Missile Studies With a Biological Target – Lovelace Foundation. (WT-1470)
33.5 The Internal Environment of Underground Structures Subjected to Nuclear Blast: I. Occurrence of Dust – Lovelace Foundation. (ITR-1447)
33.6 The Internal Environment of Underground Structures Subjected to Nuclear Blast: II. Effects on Mice Located in Heavy Concrete Shelters – Lovelace Foundation. (WT-1507)

Program 34) Physical Response To Blast Loadings

34.1 Effects of a Precursor Shock Wave on Blast Loading of a Structure – Sandia Corporation. (WT-1472)
34.2 Comparison Test of Reinforcing Steels – Sandia Corporation. (WT-1473)
34.3 Test of Buried Structural Plate Pipes Subjected to Blast Loading – Holmes and Narver. (WT-1474)
34.3a Evaluation of Nuclear Blast Effects on AEC Test Facilities – Holmes and Narver. (WT-1455)
34.4 Blast Effects On An Air-Cleaning System – Harvard University. (WT-1475)

Program 35) Radiological Defense Technologies

35.1 Penetration Into Concrete of Gamma Radiation From Fallout – FCDA. (WT-1477)
35.2 Decontamination Procedures In Residential Areas – FCDA. (WT-1478) NA
35.3 Radiological Defense Monitoring Techniques – FCDA. (WT-1479) NA
35.4 Evaluation of Civil Defense Radiological Instruments – FCDA; Radio, Electronics, and Television Manufacturing Association. (ITR-1480)

Program 36) Radiological Defense Operations

36.1 Field Radiological Defense Technical Operations – FCDA. (WT-1482)
36.2 Radiological Defense Monitoring and Data Evaluation – FCDA. (WT-1482)
36.3 Radiological Defense Operations Photography – FCDA. (WT-1484)
36.4 Aerial Monitoring Operations Development – Civil Air Patrol. (WT-1485)
36.5 Radiological Defense Training Operation – FCDA; California Disaster Office. (WT-1486) NA

Program 37) Radio-Ecological Aspects of Nuclear Fallout

37.1, 37.2, 37.3, and 37.6 Distribution, Characteristics, and Biotic Availability of Fallout – Atomic Energy Project University of California, Los Angeles. (WT-1488)
37.4 Measurement of Fast Neutron Doses by Germanium Detectors - – Atomic Energy Project University of California, Los Angeles. (ITR-1492)

37.5 Chemical Dosimetry of Prompt and Residual Radiation from Nuclear Detonations – Atomic Energy Project University of California, Los Angeles. (WT-1493)

Program 38) Effects of Radioactive Fallout on Foodstuffs

38.1-I Effect of Fallout Contamination on Processed Foods, Containers, and Packaging – Food and Drug Administration; FCDA. (WT-1496)
38.1-II Blast Effects on Glass Vacuum Containers – Food and Drug Administration; FCDA. (WT-1461)
38.2 Effect of Fallout Contamination on Raw Agricultural Products – Food and Drug Administration; FCDA. (WT-1497)
38.3 Measuring and Monitoring Training Exercises – Food and Drug Administration. (WT-1498)

Program 39) Instrumentation and Dosimetry

39.1 Radiation Measurements Utilizing the USAF Chemical Dosimeters – Air Force School of Aviation Medicine; AEC Division of Biology and Medicine. (WT-1500)
39.1a Gamma Dosimetry by Film Badge Techniques – Civil Effects Test Group. (WT-1466)
39.1b Neutron Dosimetry by the Threshold Detector Technique – Oak Ridge National Laboratory. (WT-1471) NA
39.2 Blast Measurements for CETG Projects – Ballistics Research Laboratories. (WT-1501)
39.3 Thermal Radiation Measurements – AEC. (WT-1502)
39.4 Technical Photography – EG&G.
39.5 Radiation Dosimetry for Human Exposures – Oak Ridge National Laboratory. (WT-1504)
39.6 Biological Effects of Nuclear Radiation on the Monkey (Macaca Mulatta) -- Air Force School of Aviation Medicine. (WT-1505 & WT-1542)
39.6a Large Animal Neutron-Gamma Irradiation Experiment – AEC; University of Tennessee AEC Agricultural Research Program. (ITR-1476)
39.7 & 39.7a Delayed Effects of Bomb Radiation on Small and Large Animals – Los Alamos Scientific Laboratory; Air Force School of Aviation Medicine; Ballistics Research Laboratory; Naval Medical Research Institute; Oak Ridge National Laboratory; Surgeon General. (WT-1506) NA
39.8 Depth Dose Studies With Initial Bomb Gamma and Neutron Radiation – Naval Medical Research Institute; Brookhaven National Laboratory. (WT-1508)
39.9 Remote Radiological Monitoring – AEC. (WT-1509)

Table II-4. CD NWE PROJECTS CONDUCTED ON PLUMBBOB TESTS.
Ponton et.al 1982b:205-6)

TEST → PROJECT	BOLTZMAN	FRANKLIN	LASSEN	WILSON	PRISCILLA	HOOD	DIABLO	JOHN	KEPLER	OWENS	STOKES	SHASTA	DOPPLER	FRANKLIN'	SMOKY	GALILEO	WHEELER	LAPLACE	FIZEAU	NEWTON	RAINIER	WHITNEY	CHARLESTON	MORGAN
Program 30) Shelters for Civil Population																								
30.1					X																			
3.2					X																			
30.3					X																			
30.4					X																			
30.5					X																			
30.5a					X																			
30.6 & 30.5b															X									
30.7 & 30.5c															X									
Program 31) Structures, Equipment, Devices, and Components																								
31.1					X	X			X	X		X			X									
31.2 NA																								
31.3 NA																								
31.4					X																			
31.5					X																			
Program 32) Radiological Countermeasures																								
32.1							X					X							X			X		
32.2 NA																								
32.3							X		X			X												
32.4					X		X					X												
32.4a U																								
Program 33) Biological Assessment of Blast Effects																								
33.1	2 shots not identified																							
33.2					X										X	X								
33.3	2 shots not identified																							

33.4					X											X								
33.5 U					X										X	X								
33.6 U															X									
Program 34) Effects on Aircraft Structures																								
34.1					X																			
34.2															X									
34.3															X									
34.3a U					X	X					X	X	X	X				X	X	X				
34.4															X									
Program 35) Radiological Defense Technologies																								
35.1	2 shots not identified																							
35.2 NA																								
35.3 NA																								
35.4	1 Tower and 1 Balloon not identified																							
Program 36) Radiological Defense Operations																								
36.1*U					X																			
36.2*U					X																			
36.3 *U	Same as 36.4 + 36.5																							
36.4 U												X												
36.5 NA																								
Program 37) Radio-Ecological Aspects of Nuclear Fallout																								
37.1	X				X		X					X			X									
37.2	X			X	X	X	X					X			X	X			X	X	X	X		
37.2a	X			X	X	X	X					X			X	X			X	X	X	X		
37.3					X										X									
37.4											X		X	X	X			X	X					
37.5												X	X	X										
37.6	X				X		X					X			X									
Program 38) Effects of Radioactive Fallout on Foodstuffs																								
38.1*																								
38.2*																								
38.3*																								
Program 39) Instrumentation and Dosimetry																								
39.1		X		X	X	X	X		X		X		X	X	X			X	X				X	
39.1a		X		X	X	X	X		X		X	X	X	X	X	X		X	X			X		
39.1b NA																								
39.2 U					X										X	X								
39.3																X								
39.4	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

39.5				X		X					X		X	X					X					
39.6		X		X															X					
39.6a U				?															?					
39.7																								
39.7a																								
39.8		X		X																			X	X
39.9	X				X				X			X			X				X	X			X	X

* - These projects involved monitoring of fallout and/or decontamination procedures after the shot date, and records are not clear about exact dates of monitoring or the shot for which the monitoring was conducted. (Such information may not have been of importance for the project.)

U - Uncertainty about the shots. Information not provided in report or conflicting information in different reports, or information not found.

NI - Not Identified. Report does not identify shot(s). This may have been done for classification purposes.

NA - Not Available - Report or information not available

CD NWE PROGRAMS AND PROJECTS ON HARDTACK PHASE II: 9/12/58 – 10/30/58

(Corsbie 1958: 1-19; USAEC 1969: 48)

CIVIL EFFECTS TEST GROUP

Program 34) Nuclear Effects, AEC Test Structures

34.1 Physical Damage Surveys of AEC Test Structures – Civil Engineering Test Group. (WT-1701)
34.2 Radiation Instrumentation, Radiation Shielding and Response Studies of AEC Test Structures – Civil Engineering Test Group. (WT-1723)
34.3 Blast Instrumentation, Radiation Shielding and Response Studies of AEC Test Structures – Civil Engineering Test Group. (WT-1723)

Program 37)

Further Evaluation of Tower and Balloon Shot Fallout Patterns - Civil Engineering Test Group. (WT-1724)

Program 39) Radiation Dosimetry for Human Exposures

39.1 Prompt Radiation Dose Distribution in Light Frame Houses
39.2 Attenuation of Weapons Radiation: Application to Japanese Houses - Civil Engineering Test Group. (WT-1725)
39.9a Botanic Study of Nuclear Effects at the NTS - Civil Effects Test Group. (WT-1726)

OFFICE OF CIVIL AND DEFENSE MOBILIZATION TEST GROUP

70.1 Field Test Aerial Survey Instrument V-780 – Office of Civil Defense and Mobilization, Battle Creek Michigan. (WT-1721)
70.2 Radiation Attenuation in Soil - Office of Civil Defense and Mobilization, Battle Creek Michigan. (WT-1722)
70.3 Retest and Evaluation of Anti-blast Valves – (WT-1717)
70.4 Effect of Nuclear Weapons on OCDM Family Fallout Shelter(WT-1718)
70.5 OCDM Support Blast Measurements (WT-1719)
70.6 Air Blast Phenomena in Tunnels (WT-1720)

Table 2-5. CD NWE PROJECTS CONDUCTED ON HARDTACK PHASE II TESTS.
(Reeves 1958: 133-4)

TEST→ / PROJECT	EDDY	MORA	TAMALPAIS	QUAY	LEA	HAMILTON	LOGAN	DONA ANA	RIO ARRIBA	SOCORRO	WRANGELL	RUSHMORE	SANFORD	DE BACA	EVANS	MAZAMA	HUMBOLT	SANTA FE	BLANCA
Program 34) Nuclear Effects, AEC Test Structures																			
34.1		X		X	X			X		X		X							
34.2		X		X	X			X		X		X							
34.3		X		X	X			X		X		X							
Program 37) Further Evaluation of Tower and Balloon Shot Fallout Patterns																			
37	X	X		X															
Program 39) Radiation Dosimetry for Human Exposures																			
39.1		X			X					X									
39.2		X			X	X				X									
39.9a	X	X		X	X	X		X	X	X	X	X	X	X		X	X	X	
Program 70) Office of Civil and Defense Mobilization Test Group Projects																			
70.1		X		X															
70.2		X		X	X			X											
70.3						X													
70.4												X							
70.5						X						X							
70.6			X												X				

The projects conducted by these test groups on safety tests were:
Hildago: 37, 39.9, and 39.9a
Vesta: 34.1, 34.2, 34.3, 39.9a. 70.4
Oberon: 39.9a
Catron: 39.9a
Chavez: 39.9a
Ganymede: 39.9a
Titanic: 39.9a

CHAPTER II-2. CD NWE PROJECTS BY TECHNICAL AREA

TECHNICAL AREAS FOR CD NWE PROJECTS

CORRELATION OF PROGRAM,#.PROJECT# AND TECHNICAL AREA

The correlation between the FCDA "**Program#.Project#**" and the alphabetic technical area in which the project is discussed herein is given in the following tables. For those projects that are essentially the same as a previously conducted project, the operation and project number of that earlier project are given. For projects where documentation is not available, "NA" is cited.

Table 2-6 . CORRELATION OF "PROGRAM#.PROJECT#" AND TECHNICAL AREA

UPSHOT-KNOTHOLE					
Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area
21.1	Ca	21.2	Ca	21.3	Fb
22.1	I	22.2	Fa	22.3	NA(Fa)
22.4	Aa	23.1	Ba	23.2.	Ba
23.3	Ba	23.4 to 23.14 & 23.16	Ba	23.15	Ba
23.17	E	24.1	NA(Cc)	24.2	E
24.3	D	26.1 & 26.2	Ac	27.1	Ga
27.2	Ga	28.1	Gb	29.1	Fa
29.2	Fa	29.3	Ga	29.4	Fa
TEAPOT					
Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area
30.1	Gb	30.2	Gb	30.3	Ga
31.1	Ca	31.2	Ca	31.4	Cb
31.5	Ad	31.6	Fb	32.1	Aa
32.2	Aa	32.2a	Aa	32.3	Aa
32.4	Aa	32.5	Aa	33.1	Ba
33.2	Ba	33.4	Ab	34.1 & 34.3	Ca
34.2	D	34.4	Ac	35.1	Ac
35.2	Ac	35.4a	Ac	35.4b	Ac
35.5	Ac	36.1 & 36.2	Ac	37.1	Gd
37.2	Ga	37.2a	Bb	37.3	Ba
38.1	Ga	38.2	I	38.3	Fa
38.4	NA(Ga)	38.5	I	39.1	E
39.2	D	39.3	E	39.4a	H
39.4b	H	39.4c	H	39.5	Fa
39.6	E	39.7 Part 1	Fa	39.7 Part 2	NA(Fa)

PLUMBBOB					
Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area
30.1	Ca	30.2	Ca	30.3	Ca
30.4	Ac	30.5	D	30.5a	D
30.5b	D	30.5c	D	30.6	Ca
30.7	Ca	31.1	Fb	31.2	NA(Cb)
31.3	NA(Ac)	31.4	Ac	31.5	Ac
32.1	Gc	32.2	NA(Ga)	32.3	Bc
32.4	Ga	33.1	Ba	33.2	Ab
33.3	Bb	33.4	Ba	33.5	Ab
33.6	Ba	34.1	See Project 30.4	34.2	Ac
34.3	Ac	34.3a	Cc	34.4	Ac
35.1	Gc	35.2	NA(Ga)	35.3	NA(Ga)
35.4	Fa	36.1	I	36.2	I
36.3	I	36.4	Ga	36.5	NA(I)
37.1,37.2, 37.2a, 37.3, 37.6	Ga	37.4	Fa	37.5	Bb
38.1-I	Gc	38.1-II	Gc	38.2	Gc
38.3	I	39.1	E	39.1a	E
39.1b	NA(E)	39.2	D	39.3-1, 39.3-2	E, Ba
39.4	H	39.5	E	39.6	Ba
39.6a	Ba	39.7 & 39.7a	NA(Ba)	39.8	Bb
39.9	NA See Projects 30.7 & 30.7				
HARDTACK PHASE II					
Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area	Prog#.Proj#	Tech. Area
34.1	Cc	34.2	Cc	34.3	D
37	Ga	39.1	E	39.2	Ca
39.9a	NA(Gd)	70.1	Fa	70.2	E
70.3	Ac	70.4	Ca	70.5	D
70.6	Ca				

CHAPTER II-3. CD NWE PROJECTS IN EACH TECHNICAL AREA

A. EXPOSURE PROJECTS

Aa. Food and Drugs

UPSHOT-KNOTHOLE

22.4 Forty-two different drug preparations considered essential in a post-attack environment were exposed. They were contained in glass bottles, their original commercial package units, as found on a drugstore shelf. The bottles were packed in twenty heavy wooden boxes 4" deep x 18" x 25" with a final weight of 40 lbs. On Simon, 6 of these boxes were exposed, 3 @ 1200' and 3 @ 1800' from GZ; and they were shielded by 0 to 2 feet of soil. On Harry, 11 boxes were exposed with the lids flush with the surface: 3 at 1200', 3 @ 1800', 3 @ 3,000', and 2 @ 7500'. The 3 remaining boxes were used as control samples. "Insulin and vitamin B_{12} were reduced in potency by about 10 and 50 percent", but no others showed any deterioration.(Laug 1953: 3,11,12, 15,16,18)

TEAPOT

32.1, .2, .2a, .3, .4, & .5 Six categories of foods were selected for exposure on Apple 2. The selection of foods was based on the largest volume and most frequent use in the American diet.

Bulk Food Staples – Approximately 28 bulk and retail items, e.g., sugar, flour, oleo-margarine, butter, peanuts, and lard.

Foods Heat Processed In Cans and Glass - Approximately 60 foods, e.g., vegetables, fruits, juices, sea foods, meats and poultry, soups, baby foods, and evaporated milk.

Commerically Packaged Beverages - Popular soft drinks and beer in case lots or loose and packaged in tin and/or glass.

Meat and Meat Products – Six processed meats such as ham and bacon, and five fresh meats held under refrigeration.

Semi-perishable Foods and Food Packaging – fruits and vegetables, dried fruits, breakfast cereals, and candy contained in 16 different kinds of packaging materials ranging from wood and paper to plastics and metal foil.

Frozen Foods – Six frozen foods in case lots, held in the frozen state with dry ice.

Over 100 different foods with a gross weight of about 15 tons were exposed during CUE. There were 908 cases of canned products and 3800 individual uncased units.

These six projects addressed the effects of neutron and gamma irradiation of foods, the problems resulting from fallout on foods and packaging, and the effects of blast and thermal radiation on food packaging. "Two types of exposure situations were used: critical and practical."

"Critical refers to an exposure on the fringe or within the area of total physical destruction." In this area "it would be possible for considerable amounts of foodstuffs to be recovered". There were no structures within the critical area, about ¼ mile (1380') for the Apple 2 yield; therefore, the principal procedure was to bury the food samples in shallow trenches covered lightly with 1 or 2 inches of soil.

The practical exposures were accommodated by the extensive home and industrial structures: "–varieties of foodstuffs were placed on shelves, stored in cartons in basements, or placed on large shelves such as might be found in grocery stores. Some were exposed in

locations where maximum fallout was expected and others were exposed primarily to blast.(Laug 1956: 3,9,10,11; Peterson 1955: 40-41)

Ab. Missiles and Secondary Missiles – Debris and Dust Generated From A Nuclear Detonation

TEAPOT

33.4 Studies were made of the ballistic properties of low-velocity missiles that were produced: inside houses; outside, but in the vicinity of houses; and inside small home type shelters. Missile traps consisted of a plywood frame with a cube of Styrofoam, 2' on each side, placed inside. The degree to which a missile of a given size and density penetrated the Styrofoam, was used to determine the missile's velocity and its lethality. Twenty-one missile traps were used inside the houses at 4700', 5500', and 10,500'. They were placed in basements, in or out of basement shelters, bedrooms, living and dining rooms, with their back against the wall and secured to the floor. Six more were placed about 100' behind the houses in open areas; and they were anchored with a cube of concrete.(Bowen 1956: 3, 13, 15-6, 27-8; Peterson 1955: 423).

PLUMBBOB

33.2 This project is similar to TEAPOT 33.4. The impact velocities of 17,524 missiles (stones, glass fragments, spheres, military debris or steel fragments), which occurred in open areas, houses, and an underground shelter with an open entryway, were determined. The shots used were Priscilla, Smoky, and Galileo; and the structures used were associated with other PLUMBBOB projects.(Bowen 1962: 5)

33.5 The possible occurrence of dust inside protective shelters due to a nuclear explosion was studied on 18 underground structures during PLUMBBOB. The structures were located at distances ranging from 4320 to 8400 ft from, GZ. Sticky-tray fallout collectors were used. The particulates captured in these trays came from: dust on the floor existing preshot, from "dust leaks" in some structures, and from the internal surfaces of the structures.(White 1957:3)

Ac. Miscellaneous or Diverse Objects

UPSHOT-KNOTHOLE

26.1 & 26.2 Operation HOT ROD, which exposed 5 sedans during operation RANGER, provided the basis for these civilian-vehicle projects on UPSHOT-KNOTHOLE. FCDA had been under great pressure from the public to provide definitive information on protection of persons in vehicles. Some people had apparently misinterpreted the information released on Hot Rod, and they came to the dangerous conclusion that an automobile was a sort of rolling foxhole for the atomic age.(Goodwin 1953: 8)

FCDA went to industry for cooperation. The National Automobile Dealers Association agreed to a joint Government-NADA project and donated some cars as did the Automobile Manufacturers Association. Both the NADA and the AMA brought the cars to Las Vegas at their own expense. Standard Oil of California provided gasoline. Civil Defense volunteers

drove the cars from Las Vegas to Mercury. The American Association of Motor Vehicle Administrators "smoothed" inter-state licenses. The Society of Automotive Engineers provided technical consultants and set up a 10 member committee of automotive engineers who checked the cars and assisted FCDA personnel in all logistics. After the shot, they evaluated each car. The AEC instrumented the cars for radiation and thermal measurements. Some of the cars were equipped with dummies supplied by the Darling Company, and the dummies were also instrumented.(ibid., 8-10)

The vehicles were oriented in different ways: front, rear, side and angled to the blast. Gas tanks were full and empty. Windows were open and closed. Brakes were on and off.(ibid., 10) A variety of typical passenger cars were tested. These ranged in age from 1936 to 1953 models. All major makes were represented. In addition, three mail trucks belonging to the Post Office Department were exposed at 3 ranges. (FCDA 1953b:9)

In addition to Annie, cars were exposed on Ruth, Dixie, Encore, and Grable. After the tests and post-shot evaluations, the FCDA returned the cars to their owners.(ibid.: 3)

<u>TEAPOT</u>
31.5 Thermal ignition and the response of materials were investigated by extensive exposure tests on CUE of six classes of objects:
<u>Stake-line Test</u> – Stakes of Ponderosa pine and Douglas fir were planted 500' apart in lines that extended from" 1000' to 12,000' from GZ.
<u>Treated-timber Piling Test</u> – Three stands of 10 poles that were treated by railroad industry methods for preservation and fireproofing were located at 3 ranges.
<u>Window Protective Test</u> – At 5 positions along the test line, exposure racks were mounted with window materials that attenuate thermal energy: solid aluminum sheets, Venetian blinds set at various angles, gauges of aluminum screening material, and window glass coated with Bon Ami powder, opaque paint, and a solution of whiting powder and water. Windows in some of the test houses were treated with the same materials. Mannequins in some houses were exposed to thermal radiation through the windows, and the thermal effects on their clothing were examined and compared with similar textiles mounted on exposure racks.
<u>Fabrics Test</u> – One hundred types of fabrics of various colors and chemistries were mounted on wooden plaques on test racks at each of three locations. Eight clothed mannequins were also exposed at each of the locations. Heat sensitive green paint and paper temperature indicators were placed beneath the fabrics.
<u>Oxyacetylene and Flammable-liquid Drum Test</u> – Oxyacetylene units were placed at 3 distances and flammable-liquid drums at 2.
<u>Plastics Test</u> – Over 200 samples of plastic materials were exposed at each of 3 locations. Numerous plastic articles "representative of all types widely used on the consumer market" were also placed in buildings.(Laughlin 1957: 5,6; Peterson 1955: 35-38)

34.4 The machine tools exposed on CUE were large and weighty. They are listed in the following table along with their exposure distance and weight.

Location # Machine tool	DISTANCE FROM GZ (ft)	WEIGHT (lb)	EXPECTED Pmax (psi)
Back of Industrial Wall	2,750		19
1 Prentice lathe		7,000	
1 Cincinnati mill		12,000	
1 Van Norman mill		7,000	
1 Pond lathe		10,000	
Back of Brick House 1 hydraulic press	4,700	49,000	5
In Butler Building	6,800		3
1 pressure vessel		4,100	
1 Fray mill		3,000	
1 steam oven		*	
In Armco Building	6,800		3
1 pressure vessel		4,100	
1 Fray mill		3,000	
1 steam oven		*	

* Not Available

At 2,750', an 8" thick reinforced concrete foundation and a concrete-block wall, 8" thick x 40' long x 5 ¼" high were constructed. The machines were placed on the foundation immediately behind (wrt GZ) the wall. Both the foundation and the wall represented what would be found at "the average industrial installation". The wall was intended to provide a substantial amount of heavy debris. Spare parts were placed on wall pilasters and on a bench and arranged to create missiles.

At 4,700', the press was placed 8' from the rear exterior wall of the two-story brick house. A skid of spare parts was arranged to inflict maximum damage to the press, its power unit and oil reservoir. This "location was considered to be the best available to simulate factory conditions; flying debris, falling structural members, and the gas explosion hazard" from the other projects.

Portable generators were used to provide pre-shot evaluations of the machinery which was tested through its operating ranges. Where possible, the machinery was similarly tested post-shot. Pressure measurements that were made along the Blast Line were used.(Sparks 1956: 11-13,20, 32)

35.1 Electrical equipment, representative of that in urban residential and commercial areas, was tested by the Edison Electric Institute. Duplicate electric-power installations consisting of transmission, substation, and distribution equipment were constructed at 4,700' and 10,500'. The transmission line (installed on steel towers) and the substation equipment were representative of equipment for large industrial plants. Power lines ran from poles to some houses, and parts of the systems operated during the detonation. "The damage was confined to the transmission and distribution circuits at the 4,700-ft area and --- the

equipment could have been easily and quickly repaired. In the same area, typical homes were completely destroyed."(Wood 1965: 4,9; Peterson et. al. 1955: 46-48)

35.2 CUE was the first test of civilian communication equipment, which is "generally designed for lower cost and less rigorous service" than is military equipment (Williamson 1955:14-15)

Civilian communication equipment was placed in the 7 houses on CUE. Also exposed were 150' AM broadcast guyed antenna towers, the communication antenna towers, and the sirens (which are not electrical). "Within and near these houses, communications equipment products were placed in situations that approximated, as closely as possible, the placement of such equipment in commercial buildings and in homes." As possible, identical products were exposed at two distances, which represented severe and light damage. (Williamson 1955: 3-4,17-18,45)

Equipment	4700'	10,500'
Mobile Radio Communication Systems & Units	24	20
Standard AM Broadcast Transmitting Station	8	--
Antenna Towers	2	2
Home Receiving Systems	15	14
Telephone Systems	10	2
Sound systems	12	12
Component-part Exposure Panels	8	4
Wire and Cable	8	5
Sirens	2	2
Headphones, microphones, monitors, etc.	several	several

The test showed that the equipment "was generally more resistant to nuclear explosion damage than the structures in and near which the products were exposed". (Williamson 1955: 3, 18; Peterson 1955: 49-55)

35.4a On CUE, the Liquefied Petroleum Gas (LPG) Association exposed three different types of LPG containers and systems, typical of those found at home and at storage, industrial, or utility plants:
1) A bulk storage plant, located at 4,700', was constructed which consisted of "an 18,000-gal tank, a pump, compressor, cylinder-filling building, cylinder dock, and all necessary valves, fittings, hose, accessories, and interconnecting piping". The fully-equipped cylinder-filling building was of sheet-metal, 16' x 20'; and the filling-tank contained 15,400 gal of propane (weighing over 33 tons).
2) Eight domestic type installations, each consisting of two cylinders of 100 lb LPG capacity, were installed at 4 distances. At the 1840' and the 2750' distances, two of these domestic installations were placed oriented parallel to the blast line, one on each side of a concrete simulated house wall (there were no houses at 1840' or 2750'). The remaining 4 domestic installations were located, 2 each, at 4700' and 10,500', along side and behind houses.

3) Eight 500 gal capacity systems, typical of those used for the storage of truck delivered LPG, were installed. One each was placed at the simulated house walls at 1840' and 2750'. At both 4700' and 10,500', one was placed behind a house, and 2 were in the "free field", placed parallel and perpendicular to the blast line.
Connections were made from the LPG cylinders and systems to the houses. At the time of detonation, variations of different gas flow situations were staged at the 6 houses: all appliances burning, appliances and gas shut off, or capped at cylinder. (Tucker 1956: 3,13,16-27)

35.4b The American Gas Association exposed a variety of installations on CUE for piped natural gas which included:
- underground installations (steel and cast iron piping, regulators, meters, gauge boxes, oil seals);
- piping from underground installations to connect 3 houses (2 @ 4,700' and 1@ 10,500');
- piping within 3 houses to some appliances*, others were unconnected. [*Appliances consisted of: kitchen range, refrigerator, water heater, room heater, wall heater, dryer, furnace, incinerator] The underground installations were made "in accordance with current gas industry practice". But, different types of standard components were used (e.g. different diameters of lead and steel pipe) in order to expose more types of equipment and to obtain results in various zones of damage. "Customary gas industry test instruments" were used to assess the installations both pre and post-shot.

In addition, two emergency vehicles, a heavy repair truck, and a customer service pickup truck, were located at 15,000'. The trucks were completely equipped with tools, supplies, and two-way radios.(Corfield 1965: 12-5,30,36,44)

35.5 Records materials and records storage equipment were exposed on CUE in structures or shielded locations, and just placed in the free field at distances of between 500' and 10,500' of Apple 2 GZ.
The equipment exposed was:

Class A, B, and C safes; Document Containers (aluminum foil & standard); File Cabinets; Insulated File Safe; Microfilm Cabinet; Record Storage Boxes 1 cubic ft corregated; Steel Shelving; Steel Transfer Cases; Telegraph Paper in cartons; Money Chest; Concrete block Money Chest; and Wall safe.

The structures in which some of the equipment were located consisted of: Basement of 2 story frame house (2 of them at 2 distances); 1 story frame house (2 of them at 2 distances); garage of 1 story precast concrete house; and a concrete block wall 60 inches high.

The types of records in the various pieces of storage equipment were: correspondence, microfilm, telegrams, old documents, telegraph tape, motion picture film, teledeltos paper, paper samples, transfer copy paper, and developer. Evaluation of damage was post shot inspection and photography. Pressure levels were obtained from measurements made along the blast line by other projects.(Nationall Records Management Council 1956: 5, 14-6)

36.1 & 36.2 Seventeen different companies provided mobile homes: 9 were located at 10,500', 7 at 15,000', and 1 at 16,000' on CUE. A variety of designs and sizes were tested

that ranged from: 17', no separate bedroom at 2700 lbs to 42' 10" with 2 bedrooms at 8600 lbs. They were oriented in various directions with respect to GZ; and at the time of detonation, they had variations of windows open and closed and doors open and closed.

Eleven emergency vehicles were also exposed: 1 at 1470', 2 at 4700', 2 at 10,500', and 6 at 15,000'. They were oriented either facing or broadside to GZ and were fully equipped for their missions:

American Gas Association
- Gas service truck
- Heavy-duty gas repair truck

Edison Electric Institute
- Earth boring machine
- Heavy-duty line truck
- Light-duty service truck

American Telephone & Telegraph. Co.
- Two installers' service trucks

Seagrave-Hirsch, Inc.
- Fire department pumper

Fire Apparatus Manufacturers Assoc.
- Aerial-ladder truck

Willys Motor Co.
- Jeep fire engine

FCDA
- Rescue Service truck

The main diagnostics of these 2 projects were personal inspection and photography.(Shaw 1957:25,31,33-8, 42,46,52-3) Civil defense officials had become "accustomed to thinking of damage in terms of four zones:
A damage: Building almost completely destroyed.
B damage: most buildings damaged beyond repair.
C damage: moderately damaged buildings that must be vacated during repairs.
D damage: partially damaged buildings that need not be vacated during repairs."
Post shot, the mobile homes and emergency vehicles were evaluated in terms of these damage zones.(Shaw 1957:9)

PLUMBBOB

30.4 The Mosler Safe Company contracted with Ammann & Whitney to design a vault of rectangular structure 12' 7½" x 8' 3.4" x 8' high. The walls and roof slab were 18" reinforced concrete lined with a ½" thick steel plate. The vault was anchored into a large (23' 1¾" x 33' 9") mat foundation from 2 to 6 feet thick to prevent it from overturning. The structure was 1150 ft from Priscilla GZ. "The 7½ ton door was mounted on a steel box frame weighing 14½ tons and was placed facing GZ." The vault with the door closed was essentially gastight. The longitudinal center line of the structure was radial to GZ.(Cohen 1961b: 3,11-2)

In **34.1**, Sandia provided 7 air pressure gauges for the vault: 1 on foundation slab; 1 front face; 1 door; 2 roof; and 2 rear wall. Also, free-field pressure was measured by 2 gauges on the 1150' radial but south of the vault. Sandia's Project 34.1 also conducted much more extensive pressure measurements on a 20' x 6' x 6' structure located not far from the vault, at 2000' from Priscilla GZ. Maximum deflection of the structure was measured, but the structural response was not.(ibid.:14-16; Banister 1960:5,11-17)

Projects **39.1** and **39.1a** made radiation measurements in the vault as well as along the main blast line with chemical and film dosimeters, respectively. (ibid.: 16) Temperature on the outside of the door and inside the vault was measured, and a movie camera was placed inside the vault.(ibid. 16, 43)

31.3 studies were to be made of the various aspects of previous tests on military air transportation. The possible hazards for civil air transportation were to be identified. Participation was planned for one or more shots.(Corsbie 1957: 13)

31.4 Five types of industrial doors: steel plate, cellular steel, wood plank, hollow plywood, and solid plywood, were designed and tested on Priscilla at the 3½ psi and 7 psi peak incident overpressure levels. These doors were instrumented for maximum deflection and deflection-time.(FitzSimons 1958: 3-4)

31.5 Eleven prototype anti-blast valves were exposed during Priscilla on 6 vertical and 5 horizontal mountings. The 6 vertical mountings were: a 12" valve at 100 psi; a 16" and 24" at 50 psi; and 12", 16", and 24" at 7½ psi. The 5 horizontal mountings were: two 16" and one 24" at 7 psi and one 16" and one 24" at 3½ psi. All pressure sensitive valves closed upon arrival of the shock and the thermal-triggered valve closed in advance of the shock wave. Closure times were of the order of 0.1 sec.(Allen 1958: 3-4)

34.2 Rail- and intermediate-grade steel slabs used as reinforcement in concrete slabs were exposed on Smoky. Slab pairs were placed at ground level over deflection chambers at 2 locations. Measurements were made of deflections and loading pulse.(Carlson 1959: 5)

34.3 evaluated the suitability of structural-plate pipes, as a partial substitute for heavy concrete tunnel sections in the construction of scientific stations at ranges close to nuclear detonations. Two 20' long 7' diameter structural-plate pipes were buried for Smoky at the very close-in locations of 265 and 195 psi anticipated pressures. "The depth of burial was 10' over the crown of the pipe." The principal measurements were transient changes in diameter, accelerations, and interior overpressure. Also, pre and postshot observations were conducted along with measurements of displacements. (Williamson 1960: 5)

34.4 A study of the effect of shock waves on various types of air-cleaning equipment was undertaken on Galileo. Identical ventilation systems were constructed in the one story precast house and in the chemical-plant control room of TEAPOT Projects 31.1 and 31.2 respectively. These structures witnessed the Galileo shock wave in the 1 and 3 psi range respectively.(Dennis 1962: 5, 11,16)

HARDTACK II

70.3 Since the anti-blast valves had performed so well during PLUMBBOB 31.5, it was thought that they could perform at higher pressures; and if so, their cost and/or weight could be reduced. On HARDTACK II, valves were placed at locations where the predicted pressures were 175, 150, and 125 psi. Because the test on which they were placed, Hamilton, went low, these higher pressures were not achieved.(Roembke 1958:3-4)

B. BIOMEDICAL EXPOSURES

Ba. Animals and Plants

UPSHOT-KNOTHOLE

23.1 & 23.3 To estimate the neutron contribution to the total biologically effective dose rate, dogs and mice were placed in cubical (2' on a side) containers with aluminum or lead shields to eliminate gamma radiations. The containers were located within AEC communal shelters that had soil over-cover. On Annie, the shelter was located 1500' from GZ. Ruth, Dixie, and Climax used the BUSTER 9.1b communal shelter that was 300', 6042', and 2000' from the three GZs respectively. On Harry, three shelters, located about 2350' from GZ, were constructed of a long tubular section (90" I.D.) with a ramp. A total of 24 dogs and 2760 mice were exposed in the 5 shots. They underwent post-shot examinations, and some underwent long term studies.(Bond 1953: 3,11,12,18,23-25)

23.2 Previous studies had implicated bacterial invasion as one of the important causes of death after radiation exposure. To investigate whether bacterial invasion was an important cause of death, mice were exposed to neutron radiation and to a combination of neutron and gamma radiation. At the time of death, their heart blood and spleen were examined for bacterial infections.(Silverman 1953: 3, 9)

23.4 to 23.14 & 23.16 To determine the frequencies of different kinds of mutations induced over a range of fast neutron doses, both plants and animals were exposed. Specimens were placed inside 7"-thick lead hemispheres which blocked the gammas. These hemispheres were placed at stations with increasing range from each GZ. The 3 shots used were Annie, Encore and Grable. Measurements of total neutron doses were made with ionization chambers. Plant materials included spores of over 10 fungi, buds, pollen, flowers, seeds of Detura, and maize corn. Animal species were flies, wasps, and several mouse strains. A conclusion was: "---for equal doses neutrons represent a greater potential genetic hazard than other forms of radiation from nuclear detonations." (Plough 1954: 3, 11,14)

23.15 Dogs that had been restrained and exposed within the communal air-raid shelters during Annie and Harry were studied pathologically and clinically for blast injuries. Also, two anthropometric dummies were test objects in the shelters for displacement studies that used high-speed photography.(Roberts 1953: 3)

TEAPOT

33.1 To study the effects of blast pressure on animals, 4 of the Project 34.1 shelters were used during Apple I; and 11 of them were used during CUE. A total of 277 animals were exposed, including: 66 dogs, 52 rabbits, 52 guinea pigs, 63 rats, and 44 mice.

Type of Shelter	Interior Dimensions (ft)	# on Apple 1	# on CUE	Remarks
Group shelter, partitioned, concrete	12x25x8	1	1	Belowground @ 1050'
Basement exit	3x12.66x5	3	4	Belowground 2 @

shelter, concrete				1270' & 2@ 1470'
Utility shelter, reinforced concrete	6x6x7	-	3	Aboveground @ 2250', 2750', & 3750'
Bathroom shelter, concrete	7x5x7.33	-	1	Aboveground in bathroom of frame rambler house @ 4700'
Basement lean-to shelter, wood	6x4x5	-	1	Belowground in basement of 2-story brick & cinder house @ 4700'
Basement corner shelter, wood	6x6x6	-	1	Belowground in basement of 2-story wood frame house @ 5500'

The shelters were instrumented for: pressure-time, wind effect, temperature, noise, radiation detectors, and electrocardiograms were made on 4 dogs.

An interesting observation was: "The geometry and design of the several structures markedly influenced the magnitude and character of the internal, compared with the external, pressure-time phenomena." For example, in some instances, the internal maximum overpressure (Pmax) was near one-fourth of the external Pmax; in others the internal Pmax was more than double the external Pmax.(White 1956: 3,15,24,43,48)

33.2 Rats were exposed on Apple 1 (18) and on CUE (52) "-to observe the effects of the noise from a nuclear detonation on trained rats", and "to study the effects of living through a nuclear explosion on the learning processes of the test animals". They were male albino rats, ranging in age from 120 to 150 days. Some of these rats were trained (to obtain their food by striking a card with a small white circle on a black background rather than the card with a small black circle on white background). Some of these rats were deafened prior to their exposure.

On Apple 1, 18 untrained rats were exposed in shelters at 1350'. Twenty others were kept in the laboratory, unexposed, as a control group. On CUE, the animals were divided into 3 groups with each group containing deafened trained, non-deafened trained, and non-deafened untrained rats. One group was kept in the laboratory as a control group, and the other 2 were placed in shelters at 1470'. The maximum noise intensity and the duration of the noise were measured. Beta and gamma radiation was measured by film badges and neutron dosimeters. Also in the shelters, pressure-time and temperature-time were recorded.

The rats were recovered at about +10 hours, returned to the laboratory, and trained or retrained*. (Hirsch 1956: 11-2,17,21-2,27,28) [*Footnote: "The difference in the number of trials to learn and the number of trials to relearn is known as the retention score. The larger this difference, the greater

is the retention—". Conversely for forgetting.] The mere passage of time causes some normal loss in retention, and the unexposed control group rats provide a score for "normal" loss of retention. Any additional loss could therefore, be attributed to exposure.

37.3 was conducted by UCLA School of Medicine as part of its Atomic Energy Project. Rabbits and rats were subjected to controlled inhalation exposures to dusts from radioactive siliceous material from Area 3. Several groups were exposed to similar conditions in the field at 7 and 106 miles. Conclusions were that --"there is no apparent situation in nuclear warfare where, during the first few days after detonation, one could inhale sufficient radioactive material to induce a serious radiation injury to lungs or intestines without simultaneously being subjected to supralethal doses of external beta-gamma radiation."(Taplin 1957:3-4)

PLUMBBOB

33.1 exposed dogs, rabbits, guinea pigs, and mice in two underground partitioned shelters, one shelter on Kepler and one on Galileo. The biological blast effects were assessed by measurements of: pressure, thermal radiation, ionizing radiation, and dust. The number of exposures on (Kepler, Galileo) was: dogs (14,10); rabbits (20, 30); guinea pigs (60, 40); and mice (220, 160).(Richmond 1959: 5, 11, 23-4)

33.4 Fourteen dogs were exposed near: planted gravel, a concrete-block wall, and glass mounted in the open and in houses. Results indicated the feasibility of utilizing missile data as a means of quantitatively assessing biological hazards and predicting dangerous wounds.(Goldizen 1960: 5)

33.6 Mice were variously located in the French and German structures (PLUMBBOB 30.6 and 30.7). Their post-shot examination provided an indication of the environment experienced and an indication of how humans would be affected. The main chambers near the entry doors of the German shelters had "- - over 100 r, a biologically significant dose. In contrast, the environment within two of the French shelters appeared to be quite acceptable". The peak pressures were "insignificant".(Richmond 19598: 5)

39.3-2 Part I (39.3-1 in Section E) measured the transient air temperatures within the blast-biology underground shelter located 1050' S of GZ on Galileo.(Grieg 1958: 13) Part II evaluated the thermal burns received by 8 Chester White pigs.(Grieg 1958: 27)

39.6 To correlate neutron and gamma measurements with biological response, Macaca mulatto monkeys were exposed to neutron and gamma radiation on Wilson (72 monkeys exposed and 8 control monkeys) and Fitzeau (80 monkeys exposed and 8 control monkeys). A group of 8 monkeys were placed at each of 9 distances from Wilson GZ and at each of 10 distances from Fitzeau GZ. Every other animal was monitored with chemical dosimeters for gamma-ray dose; threshold detectors for neutrons were placed at each distance; and there was over-all area dosimetry coverage from Project 39.5.

The dose to produce death in 30 days in 50 percent of the animals was determined. Where mortality did not occur, the monkeys were followed for long term effects such as cataracts,

bone-marrow change, shortened life span, and carcinogenesis. A two year evaluation report was written as well as one giving results after 30 days.(Pickering 1958: 5, 11-14; Pickering 1959: 5, 12-15)

39.6a To obtain a comparison between how small and large animals react to radiation exposure, burros were exposed to the same conditions as were macaca mulatta monkeys during Wilson and Fitzeau. A group of 102 burros (60 male and 42 female) was studied: 88 were exposed, 13 were kept as on-site control, and one was anesthetized, exsanguinated and embalmed for the purposes of the dosimetry study. Prior to exposure, the burros "were kept in shaded or partially shaded concrete-floored pens and fed good quality alfalfa hay and oats".

The exposure shelters consisted of 44 sections of steel culvert pipe (5' diameter and 13' length), each of which was designed to hold 2 burros placed nose to nose. The 11 rows of 4 shelters each were positioned to bracket the radiation lethality range. One additional shelter was positioned in the front row to contain the dosimetry cadaver. All shelters were placed 6" below ground surface and toe-nailed to the earth by 2.5' spikes as well as being anchored with 6 cables. "The animals were placed inside the shelters – and they were satisfactorily maintained in position during a 48 hour period of schedule changes. Removal of the animals was accomplished over a 5 hour period commencing approximately 4 hours postshot. The burro is by nature a stubborn animal, so ultimately the method of placement and recovery adopted utilized a sling arrangement lifted by a large self-propelled derrick."(Kuhn 1958: 1-15).

39.7 and **39.7a** Project 37 was a long term study of the delayed effects of "acutely delivered" radiation on mice. However, because of infection in the colony, the project became 39.7a, to collect and evaluate information of 3 to 4 species and sizes of mammals in internally controlled fields. This work was to be coordinated with projects 39.5, 39.6, and 39.8 on 2 shots.(Corsbie 1957: 64)

Bb. Phantoms

TEAPOT

37.2a During Operation CASTLE in the Pacific, "it was found that skin burns on humans resulted from fall-out material that was deposited on the skin and that all or nearly all of the injury resulted from the beta components of the radiation". To determine the probable beta radiation dose from fall-out that arrives at the germinal layer of human skin (which lies directly beneath the outer layer of skin) special film-packet holders were built. They consisted of films such as mylar and aluminum which filtered the fallout about the same as does the outer layer of human skin. These film packets were placed about 10 to 160 miles from GZ on Turk, Apple I, Met, and Apple II.(Dickey 1957: 3-4, 9-12)

PLUMBBOB

33.3 Anthropomorphic dummies and equivalent spheres (idealized models having an acceleration coefficient about equal to that of the dummy) were used on Priscilla and Smoky

to determine the velocity-time and distance-time histories resulting from blast winds. Phototriangulation was used for recording their movement.(Taborelli 1959: 5, 17-19)

37.5 Human phantoms were placed at positions that received prompt neutron and gamma radiation exposures in the dose range of medical interest. The feasibility of using chemical dosimeters for gamma exposures from both fallout and prompt radiations was demonstrated. The responses of chemical dosimeters to gamma rays plus neutrons provided a useful index of the total exposure to humans.(Taplin 1960: 5)

39.8 For both initial neutron and gamma radiations, phantoms were used to determine: 1) the relation of incident dose to absorbed dose, and 2) the distribution of absorbed dose. The ways in which a human can be represented are "interesting". For gamma measurements, masonite, having a density of 1.08, was used to make discs that were assembled to simulate the torso of an average-sized man, and a chemical dosimeter was placed inside. For neutron measurements, a liquid was used that consisted of 2.92 kg of cane sugar and 1.78 kg of urea with 5 gal of distilled water. A variety of neutron dosimeters were used, some of which were placed within the liquid phantom, others external to the phantom on Franklin, Wilson, Charleston, and Morgan.(Imirie 1958: 5-6,13,17-22)

Bc. Humans

PLUMBBOB

32.3 Project personnel were present inside a "high-performance radiological shelter" during the detonations of Diablo, Kepler and Shasta. The shelter was a standard 25 by 48 ft Armco Multi-plate. It had a minimum earth-cover thickness of 3 feet which provided an average shielding reduction of a factor of about 10,000. It was located 5200' north of Diablo GZ, 4.75 miles north of Kepler, and 2 miles north of Shasta. During their pre and post shot time in the shelter, personnel took a variety of measurements to evaluate shelter performance. They also tested several methods for determining the radiological situation outside the shelter.(Strope 1959: 5,13-4, 37)

Prior to Diablo, three areas located between about 200 and 1000 yards from the shelter were pre-designated and staked as reclamation areas. These 3 areas were each about 500 ft on a side, and they would be worked with heavy earth moving equipment to try different decontamination techniques. This work would begin after radioactivity from the fallout had subsided to a safe level which would be determined by monitors who were in the shelter at detonation time.(ibid.,17)

Sixteen people occupied the shelter during Diablo. Fallout arrived at the shelter about 6 min after the Diablo burst. The higher than expected radiation readings forced work outside of the shelter to be postponed until D+2 when the post detonation schedule would be followed. Shelter personnel left the area at about H+8hr, two persons remaining to continue data collection.

The Post Detonation Schedule had two 2-man monitor teams leave the shelter, man jeeps, and survey 2 of the reclamation areas. If the levels are OK, grading and scraping begins and

monitoring continues. Such work continues for about 5 hours, after which the shelter is closed; and personnel return to CP Rad-Safe area.(ibid.: 145)

Although the wind structure at the time of Kepler was favorable for fallout at the shelter, the yield of Kepler was less than anticipated, fallout was negligible; and no useful data were collected. Five persons occupied the shelter during Shasta. Fallout arrived at the shelter about 10 minutes after detonation, and the Post Detonation Schedule started at about H + 1 hour. (ibid.: 37,40)

C. STRUCTURES

Ca. Homes and Shelters

UPSHOT-KNOTHOLE

21.1 During BUSTER 9.1a, very small home shelters, many of which were constructed of wood, were tested. The results showed weaknesses in the entrances. New designs were developed with building materials of a more permanent nature for exposure on UPSHOT-KNOTHOLE. In a joint project with the AEC, eight earth-covered home–type shelters were constructed and exposed at ranges of : 1230' (1 shelter with expected over pressure of about 45 psi), 1450'(1 @ 30 psi), 1800'(5 @ 20 psi), and 3500' (1 @ 2psi). Different designs and construction materials were used for each shelter, and all had 3 feet of earth covered except for the shelter at 1,450 feet, which had 4 ½ feet. The materials for the shelter at 3,500 feet cost about $180. Some mannequins were placed in shelters at each range.(FCDA 1953: 9; Byrnes 1953: 3-4, 9-10) These underground shelters were indeed small, the place for people being only about 4'x4'; and entering one would have been grim.

21.2 Two typical center-hall, two-story frame houses, without utilities (plumbing, heating, or wiring), were constructed at 3500 and 7500 feet from Annie GZ. (Byrnes 1953a: 3; Goodwin 1953: 2) "These houses are one of the most common types of American home. At present East Coast prices they would cost about $20,000 each, complete with utilities."(Goodwin 1953: 4) Exposure of the houses was for public demonstration purposes and to study the effects of: gamma-radiation, thermal radiation, and blast.(Byrnes 1953a:3) The houses were sparsely furnished with Government surplus furniture.(Goodwin 1953: 4) Department-store mannequins, provided at no cost by the L. A. Darling Company of Bronson, Michigan, were placed in the rooms and the basement shelters. Each basement included one lean-to type shelter and one corner room shelter. The lean-to shelter used about $40 worth of materials, and the corner room shelter used about $95 worth. About 100 film badges were placed in each basement and the basement shelters to determine the penetration of gamma radiation.(FCDA 1953b: 5;Byrnes 1953b)

TEAPOT

31.1 Five pairs of houses, ten in all, were constructed and became a focus of public attention. These houses were also the venues for various other projects.

TYPE OF PAIR OF HOUSES	DISTANCES FROM GZ (feet)	ESTIMATED OVER-PRESSURES (psi)
TWO-STORY BRICK & CINDER BLOCK HOUSES Two-story, basement, center-hall wall-bearing with 8" masonry walls. 2 basement shelters each. Similar to the frame houses on Annie in 1953.	4,700 10,500	5 1.7
ONE-STORY FRAME RAMBLER HOUSES Wood frame rambler type, built on a poured-in-place concrete slab at grade. Bathroom was designed as an aboveground shelter with 8" thick reinforced concrete walls and ceiling.	4,700 10,500	5 1.7
ONE-STORY PRECAST CONCRETE HOUSES Made of 6" thick pre-cast lightweight expanded shale-aggregate reinforced concrete wall and partition panels.	4,700 10,500	5 1.7
ONE-STORY CONCRETE BLOCK HOUSES Built of reinforced lightweight aggregate concrete blocks.	4,700 10,500	5 1.7
REDESIGNED TWO-STORY WOOD FRAME HOUSES Similar in size and layout to the houses tested in 1953. Based on 1953 findings they were redesigned to strengthen the structure so far as possible within an increase of approximately 10 percent in building cost. Three types of basement shelters each.	5,500 7,800	4 2.5

(Randall 1961:13-17)
For comparison, housing in areas of the country subject to hurricane winds of up to 120 miles/hour are designed to resist overpressures of approximately 0.25 psi. (Randall 1961: 78)

Diagnostics consisted of visual inspection, and extensive still and motion picture photography. About 1500 dosimeters were placed in the houses and basements. Pressure versus time and total thermal energy instrumentation and results were provided by projects 39.2 and 39.3.

31.2 Two each of three industrial building types, suitable as small warehouses or shops, were constructed of metal. Standard construction was used; they were not designed to resist atomic blast. Each type of building was placed at 6,800' and at 15,000'.

ARMCO buildings – frameless steel buildings, 24'x 36'
Behlen buildings – frameless steel buildings, 28' x 32'.
Butler buildings - rigid steel-frame, 24' x 48'.

Also, a Chemical Plant Control Room building constructed of gypsum with a steel-reinforcing web was designed to protect delicate chemical and electronic controls in processing plants. Union Carbide and Carbon Corp. tested this structure at 5,500'. Gamma radiation film badges were placed in the buildings. Postshot displacements were determined.(Johnston 1956: 13-18,37; Peterson et. al. 1955: 31-32)

34.1 & 34.3 Seven types of shelters were constructed and tested on Apple 2, and 2 of these types were tested on Apple 1.

SHELTER TYPE	SHOT	DISTANCE FROM GZ(ft)	INSTRU-MENTATION
BASEMENT LEAN-TO			
Brick house	Apple II	4,700	1 Pressure
Brick house	"	10,500	
Frame house	"	5,500	
Frame house	"	7,800	
BASEMENT CORNER ROOM			
Brick house	Apple II	4,700	
Brick house	"	10,500	
Frame house	"	5,500	1 Pressure
Frame house	"	7,800	
BASEMENT REIN-FORCED CONCRETE			
Frame house	Apple II	5,500	1 Pressure
Frame house	"	7,800	
BATHROOM REINFORCED CONCRETE	Apple II	4,700	1 Pressure
Rambler house	"	10,500	
Rambler house			
UTILITY			
Masonry	Apple II	2,250	
"	"	2,750	
"	"	3,750	
Reinforced concrete-	"	2,250	1 Pressure
(poured in place)	"	2,750	1Pressure
"	"	3,750	1Pressure
Reinforced concrete-	"	2,250	
(precast)	"	2,750	
"	"	3,750	
BASEMENT EXIT			
Closed	Apple I	1,360	
Partly Open	"	1,350	
Open	"	1,350	
Closed	Apple II	1,270	
Open	"	1,270	

Closed	"	1,470	
Open	"	1,470	
GROUP			
Structural	Apple I	1,050	A
Biomedical	"	1,050	B
Structural	Apple II	1,050	C
Biomedical	"	1,050	B
BLAST LINE			
	Apple I	1,050	1 Pressure
See TEAPOT Project 39.2	"	1,350	1 Pressure
	Apple II	1,050	1 Pressure
	"	1,270	1 Pressure
	"	1,470	1 Pressure
	"	2,250	1 Pressure
	"	2,750	1 Pressure
	"	3,750	1 Pressure
	"	4,700	3 Pressure
	"	10,500	3 Pressure
	"	15,000	1 Pressure

A = 3 pressure & 1 noise
B = 12 pressure, 1 noise, 2 temperature, & 1 dynamic pressure
C = 3 pressure, 1 noise, & 1 acceleration
The first 4 of the shelter types given in the above Table were placed inside one of the houses described in 31.1. The 3 different Utility shelters were made of three different materials and tested at 3 locations. They were aboveground shelters that could also be used as storage shelters. They might be connected to a house through the basement walls.

None of the Basement Exit type of shelters were attached to a house basement, but they were constructed underground at basement level. The doorway that would have led from a basement to the Basement Exit shelter was constructed as a concrete wall. The Basement Exit shelters were all constructed the same, but they were tested with their exit doors in different configurations: open, closed, partly open.

The 4 Group shelters were designed to accommodate 50 persons, at about 5.75 ft^2 per person (less than 2'x3' per person). They were constructed the same except for an interior partition. One of each pair of the Group shelters was modified by a reinforced-concrete partition dividing the shelter into two chambers, each 12'x12'x8'high. (Vortman 1956a: 13-29)

PLUMBBOB

30.1 This extensive project was conducted with the Air Force as DoD's Project 3.6 on PLUMBBOB, see Part I Chapter 3, Technical Area G.(Neidhart 1957)

30.2 The largest shelter tested on PLUMBBOB was 87'x 87' with nine interior columns 29' on center – a reinforced-concrete dual-purpose underground parking garage and personnel shelter. It was constructed for Priscilla at 1600', with a predicted 35 psi pressure. The entrance was by a 14' side vehicular ramp along one side of the structure. The roof slab was

3' below grade; the walls12" thick; and the exposed wall along the ramp was 4'6" thick for radiation protection. Blast and radiation instrumentation was used.(Cohen 1961a: 5, 13,24)

30.3 Prior to megaton weapons, family type shelters were developed to protect occupants from peak incident overpressures of about 15 psi and fallout radiation equivalent to about 3' of earth cover. This project tested the most recent shelter designs for overpressure of 30 psi or more. Space was provided in the shelter for storing supplies to sustain 6 persons for 7 days.

Three shelters were built and located at the 65, 48, and 30 psi overpressure levels. As a shelter was entered, stairs led to a level about 6 1/2' below ground surface to the entrance corridor with two 90° bends. After the second bend was a hallway about 5' long with storage on one side that led to the main shelter area which was about 10' x 7' x 6 ½' high. This is ~ 12 ft^2/person or 76 ft^3/person. Ten ft^2/person had been established as the minimum living space, which is roughly twice the square footage of a coach seat on a Boeing 747.

On top of the ~ 8" concrete roof, there was 5'4" of earth cover through which protruded an antenna block, an air-driven exhaust ventilator, and another vent pipe. A price for this shelter was not quoted, but it was obviously much more expensive than the family shelters tested at BUSTER. This shelter represents the tested state-of-the-art for family shelters at the end of atmospheric testing.

Permanent deformations and time-deflection were measured in the 30 psi shelter. Radiation instrumentation was "comprehensive and included both gamma and neutron measurements" conducted by projects 39.1 and 39.9.(FitzSimons 1957: 3-4,9-10, 14-8, 25-6)

30.6 The policy of the U.S. Government to furnish the governments of friendly nations with unclassified information on nuclear effects led to the participation of the Service National de la Protection Civile (SNPC) of France on PLUMBBOB. SNPC used their own resources to developed designs for the shelters and plans for an extensive test program that would provide information and data of value to FCDA as well as SNPC. SNPC engaged Ammann & Whitney as their US agent.(Cohen 1962: 6)

Five French structures were constructed and tested on Smoky.
<u>Structure II-1</u> Rectangular, 46' 7" x 13' 9" x 11' 5 ½" high; 3' 11" earth cover; poured-in-place reinforced concrete. Consisted of: entrance stairs, antechamber, the main body, emergency exit tunnel and emergency exit shaft. With a stated capacity of 50 persons, this provided nearly 13 ft^2/person or 150 ft^3/person.

<u>Structure II-2</u> Cylindrical, main body about 19' 6" long and about 7' 2" inside diameter; 4' 9" earth cover; 12 circular precast reinforced-concrete elements 1'6 ½" long. Consists of main entrance shaft with spiral steel stairs, entrance antechamber, precast body, exit chamber, and emergency exit shaft. Capacity 32 persons, maximum. This shelter would be more cramped with about 7.3 linear inches per person and nearly 100 ft^3/person. (Some sort of submarine style bunks might have been envisioned.)

Structures II-3, II-4, and II-5 These 3 structures "represent entrances for typical shelters; they consist only of the stairs and one antechamber. Ventilation systems, which normally would not be placed in the antechamber of a typical structure, were added to these structures for this test. These structures "provided for comparative evaluation of 3 different types of door and the 3 different ventilation systems."(ibid. 19-24, 30)

The reinforcing steel, doors, ventilation equipment, precast rings for the circular structure and instrumentation were shipped from France. Preshot and postshot precise-location surveys were made to determine displacements.

Instrumentation was extensive. The French provided instruments for measuring: pressure; deformation and vibrations; stresses and strains; heat (cal/cm^2) and temperature; nuclear radiation and contamination, and miscellaneous(e.g. dust collector, lighting, communications, etc.). The French instrumentation was installed in the shelters by the U.S. members of Project 30.5b who assembled and installed it per specifications and guidance in meetings with SNPC. (ibid. 5, 42-3; Meszros 1961: 3)

For Project 30.5b BRL personnel also placed their own self-recording pressure-time gauges in and outside the shelters and in the entranceways. The US also fielded additional radiation equipment. The installation of all radiation-recording instruments, including the French equipment was performed by Projects 30.5b, 39.1a, and 39.9.(Cohen 1960: 43) Also, a wire-mesh cage containing 20 mice was placed in each structure by Project 33.6. The objective was to follow their mortality post shot and to relate the cause of death "to a specific environmental factor".(Richmond 1959:5)

30.7 The U.S. Government also furnished the West German Government with unclassified information on nuclear effects, and this led to their participation in PLUMBBOB. Like France, West Germany developed designs for the shelters and plans for an extensive test program that would provide information and data of value to FCDA as well as to themselves. West Germany also engaged Ammann & Whitney as their US agent.(Cohen 1962: 7)

Nine West German structures of three different types were constructed and tested on Smoky. All 3 types were designed for 25 persons.
1) Type A Rectangular consists of: entrance stairs and ramp, vestibule, main shelter body, exit chamber, emergency exit tunnel, vertical exit shaft, and a ventilation shaft. General overall dimensions 13' 9" x 35' 5" x 11' 5 ½" high; earth cover 4'. Four, at predicted overpressures of 265, 199, 132, and 88 psi.

2)Type A Circular consists of: a protracted entranceway, vestibule, main body, exit chamber, and combination emergency exit and ventilation shaft. Overall length of the cylinder is 44' 7 1/2 ", and its interior radius is 4' 1 ¼"; earth cover 5' 3". Two at 199 and 132 psi.

3)Type C Rectangular consists of: a double entranceway (ramp and stair) leading to a common landing, entrance vestibule, main body, exit chamber, emergency exit tunnel, and

exit shaft. Excluding emergency tunnel, over-all dimensions are 20' 4" x 17' 8 ½" x 6' 6 ¾" high; earth cover 3'. Three at 29, 15, and 7 psi.

A and C Rectangular provided 19.5 and 8.1 ft^2/person with volumes of about 223 and 51 ft^3/person respectively. A Circular provided about 1.8 linear feet/person with a volume of 95 ft^3/person.

Reinforcing steel, doors, and ventilation equipment were received from West Germany and were incorporated in the shelters. Preshot and post shot, precise location surveys were made to determine displacements.(ibid. 5, 19-21,

The major portion of the instrumentation used in the structures was U.S. equipment provided by FCDA. Pressure instrumentation was installed in the structures by the BRL members of Project 30.5c. Five self-recording pressure gauges, supplied by the West Germans, were positioned along the blast line by BRL who also installed the U.S. blast-line pressure instruments for DoD on Smoky. BRL also installed and recorded displacement, acceleration, and deflection in the structures.

In Type A Rectangular at 132 psi, "concrete blocks were cast around concrete-filled rubber boots" so that the combination had a weight about that of an average human. Three such "human weights" were placed on 3 different types of flooring and instrumented with accelerometers. The objective was "to ascertain the effects on the human body of the blast accelerations. " (ibid 3, 41)

The West Germans supplied some radiation measuring instruments that were installed by US personnel on the measurement projects. US radiation instrumentation was also placed inside the shelters and the blast line. The installation of all radiation instruments, including the German equipment was performed by Projects 30.5c, 39.1a, and 39.9.(Cohen 1962: 40)

As in the French shelters, a wire-mesh cage containing 20 mice was placed in each of the West German shelters by Project 33.6.(Richmond 1959: 5) One or more of two different types of dust collectors were also placed in each structure by Project 33.5. The objective of gathering dust was to determine its particle size and, if possible, to establish its source, (i.e., dirt on the floor, spalled from ceiling, wall, or floor). (White 1957:3-4,11-2)

<u>HARDTACK II</u>

39.2 Seven Japanese-style houses were constructed and exposed during Mora, Lea, and Socorro.(Jackson 1993: 19-5/6)

70.4 constructed family fallout shelters at 5, 10, and 20 psi ranges of a blast scheduled for Area 9. After construction, the shot was moved to another area.(Reeves 1980: 96)

70.6 Self-recording gages were placed in 2 tunnels for 2 events. The objective was to learn more about blast effects generated inside tunnels from a detonation within the structure and from the piston action of the tunnel walls. Not all gages were retrieved.(Reeves 1980:97)

Cb. Structural Components

TEAPOT

31.4 Test pits 22' x 22' x 4' deep were dug at 3 ranges for the exposure of common structural beams (slabs) to dynamic loading. The ranges were: 2750', ~10psi; 4700', ~ 5 psi; and 15,000', ~ 1 psi. Each pit contained 9 slabs 15' or 20' long by 2' width. The slabs were placed horizontally on a ledge in the pit walls with the top of the slabs flush with ground level. In each pit, there were 3 sets of slabs composed of: reinforced concrete, a cellular steel, and a structural steel unit.(Clark 1955: 9-10; Peterson 1955: 33-34)

PLUMBBOB

31.2 One windowless model building and 6 wall specimens of reinforced clay masonry were to be exposed at different locations. Displacement and deflection-time measurements were to be made on 1 shot.(Corsbie 1957:12)

Cc. AEC Test Site Facilities

UPSHOT-KNOTHOLE

24.1 The title of this project is "Evaluation of Communal Shelters" by the AEC. Documentation could not be located. The AEC conducted a variety of projects in cooperation with AFSWP which addressed communal shelters. Projects that addressed the condition of various structures at different dates post shot were also conducted in cooperation with AFSWP.

PLUMBBOB

34.3a Pre and post test observations were made of AEC test structures at NTS. These structures were exposed to blast but were not primarily intended for the study of response to blast. Such studies would lead to more economical and improved design of AEC test facilities. Four test structures were observed: A retaining wall; Guyed towers; An underground concrete shelter; and Two bell-shaped protective covers.(Cameron 1959: 5,7)

HARDTACK II

34.1 recorded and evaluated air blast and thermal damage to AEC structures with emphasis on the study of structures that had been exposed to high levels of overpressures and thermal radiation. As a result, the tower used for Boltzman was reused for Quay. Low pressure structural damage was also evaluated, wrt over pressure and type of construction, for a group of wood-frame houses used in Mora, Lea, and Socorro as part of Program 39.(Cameron 1961: 5,15, 39)

34.2 studied the effects of air-burst nuclear explosions on underground structures. The balloon tests of Mora, Lea, and Socorro were used to examine effects on 3 structures in Area 7. The balloon test Rushmore was used to study one structure in Area 9. These 4 structures were all used on PLUMBBOB and were of "typical blast-resistant reinforced-concrete construction". Accelerations and radiation measurements were made in these structures.(Cameron 1962: 5, 11,17)

D. MEASUREMENTS OF FREE-FIELD AIRBLAST GROUND MOTION, AND STRUCTURAL RESPONSE

UPSHOT-KNOTHOLE

24.3 Measurements made by Vitro Corp. included overpressure, acceleration, internal displacement, strain, and air temperature versus time. They were made near and within the two communal shelters. (Ruhl 1953: 3)

TEAPOT

34.2 "Prior to TEAPOT, no successful experimental evaluation had been made of the effect of a nonideal shock front on the blast loading of a structure." To address this issue, a structure 6'x6'x36' was located 1850' from the GZ on Turk. At this distance, the structure was expected to experience a nonideal shock with an overpressure of about 14 psi.

The structure was demolished by the blast. However, records were obtained for nearly 0.6 sec which indicated that the precursor was weaker than expected, but the peak overpressures on the front of the structure were in excess of 100 psi which indicated an unexpectedly high contribution from drag pressure. (Vortman 1956b: 3-4,11)

39.2 Sandia Corporation provided instrumentation and measurements consisting of: overpressure, temperatures, dynamic pressure, and noise on Apple 1 and Apple 2. Thirty four channels were instrumented on Apple 1 and 50 on Apple 2. This instrumentation was used along the blast line at the 34.1 locations. Pressure, temperature, and magnitude of the winds were measured in Project 33.1 which exposed dogs. Noise was measured in Project 33.2 which exposed rats. Also, pressure was measured within each type of personnel shelter exposed in Program 34.(Rollosson 1955: 3-4, 11-3)

PLUMBBOB

30.5 BRL made measurements of air-blast and ground-shock loading and response for the CD structures projects 30.1, 30.2, 30.3, 31.4, and 31.5. The report of this project contains a review of the instrumentation used which essentially represents the state of the art at the end of atmospheric testing. BRL also conducted Project 1.1 for the DoD which was also widely used by the CD structures projects. (Meszaros 1960a: 5)

30.5a Armour Research Foundation measured deflection and strain versus time on the 30.1 domes which required the construction of two instrumentation shelters. One was located near the 70 psi dome, and the other was located near the 35 and 20 psi domes for their measurements. These 2 shelters had concrete walls and roof 1 1/2' thick and consisted of:

Instrument Room	9'x12'x8'high
Battery Room	4'x'6'x8'high, and
Escape Hatch	36"x36" with built-in ladder

The rooms and hatch were themselves located inside non-responding concrete domes of 2' shell thickness. Earth cover of 5' was on top of the dome containing the rooms and hatch. Lighting, power, ventilation, and cable ports were included in the shelters, as was power for the operation of the instrumentation installed in the Project 30.1 domes. Seventy three channels of instrumentation were used.(Brittain 1957: 3-4, 8-14)

30.5b BRL measurements for the French shelter, see above Part II, Technical Area Ca, Project 30.6.

30.5c BRL measurements for the West German shelter, see above Part II, Technical Area Ca, Project 30.7.

39.2 BRL provided blast measurements for static and dynamic pressures both inside shelters and in the free field on 4 projects (32.1, 33.1, 33.2, and 34.4) during 8 shots. In addition, BRL obtained measurements on various structures tests in Projects 30.5b and 30.5c as well as free-field data for the French and German shelters, 30.6 and 30.7.(Meszaros 1960c: 5-6, 17)

HARDTACK II

34.3 attempted to measure the acceleration of underground shelters as well as the adjacent free-field acceleration. Low pressures due to low yields inhibited data acquisition.(Reeves 1980: 100)

70.5 provided pressure-time and displacement-time measurements for 70.3 and 70.4.(Reeves 1980: 97)

E. MEASUREMENTS OF THERMAL AND NUCLEAR RADIATIONS, NEAR FIELD, DURING TEST

UPSHOT-KNOTHOLE

23.17 NRDL measured neutron radiation inside and outside lead hemispheres during Annie, Encore, and Grable. The lead hemispheres were placed at stations with increasing distances from GZ on Annie(27), Encore(29), and Grable(25). Gold, sulfur, and manganese detectors were used to measure the neutron flux within certain energy regions.

NRDL also measured the neutron dose inside of communal shelters. The shelters used were each constructed of 2 sections of culvert pipe, each 24' in length and 8' in diameter which were joined together and buried about 3.7'. These communal shelters were used in shots Annie (2 shelters), Ruth (1), Dixie (1), Harry(3), and Climax(1). (Tochilin 1953: 3,13-23, 37-8)

24.2 Gamma and neutron measurements were made inside the AEC communal shelters on Annie and Harry. Gamma was measured with film dosimeters; total dose and neutron with "tissue equivalent" ionization chambers and fission threshold detectors.(Deal 1953: 3)

TEAPOT

39.1 Gamma radiation measurements were made with about 825 film dosimeters placed: outside in the free field at various ranges with Project 39.6 and Project 39.7; inside aluminum hemispheres; inside lead spheres; outside with above and below ground placements. Nearly another 1500 dosimeters were placed in the houses of Project 31.1, and another few

hundred were placed in the shelters of Project 34.1. Also, about 55 were in the commercial and industrial buildings of Project 31.2.

About 200 measurements of neutron fluxes were also made with gold and sulfur threshold detectors. Cooperative studies were conducted with Projects 39.6 and 39.7on the effects of neutrons on film dosimeters.(Deal 1957: 5-6, 15-19)

39.3 The thermal flux per unit are was measured at 5 distances from Apple 2. Power failures and blast damage caused the loss of two stations; but 3 stations at 5500', 8800, and 10,500ft provided data which indicated that the thermal flux per unit area follows the inverse-square-law within the limits of reasonable experimental error.(EG&G Inc 1956:3-4)

39.6 Chemical dosimetery techniques were evaluated; experiments were conducted on neutron induced residual gamma radiations; and the feasibility of using 2 types of chemical dosimeter systems for the measurement of both fast neutron and gamma radiation was investigated. Approximately 20,000 dosimeters of the 2 types were used. (Taplin 1955: 3-4)

<u>PLUMBBOB</u>

39.1 Two types of dosimeters measured neutrons and gammas on most of the PLUMBBOB tests. One was sensitive to fast neutrons and gamma rays, and the other was not sensitive to fast neutrons but responded to gamma radiation. (Sigloff 1958a: 11,63)

39.1a Measurements were made by EG&G of gamma-radiation dose as a function of distance from GZ on 15 shots. Measurements were made using dental film packs housed in film badge holders designed by EG&G. (EG&G 1958: 5)

39.1b Film dosimeters from EG&G were to be placed at 100 yard intervals from GZ on 17 shots. Support was to be given to all CD projects desiring gamma dosimetry.(Corsbie 1957: 57)

39.3-1 EG&G measured thermal flux per unit area at 5500', 6800', and 10,500' from Galileo. Two closer stations failed. The three distances measured followed the inverse-square-law falloff with distance.(EG&G 1956:3-4)

39.5 Measurements on 6 events consisted of:
1) Gamma dose and neutron-energy spectrum in air.
2) Angular distribution of gamma dose and neutron-energy spectrum.
3) Attenuation of neutrons and gamma rays in sand-filled boxes.
Detectors were mounted on "goal posts" that were located at various distances from GZ.

For Fitzeau, two identical light-frame houses were constructed 1000 yards from GZ. One house directly faced GZ, the other faced directly away. All wooden surfaces exposed to direct thermal radiation were covered with aluminum foil to prevent ignition. Dosimeters placed inside the houses were attached to a cable to pull the dosimeters from the wreckage postshot. To aid ongoing studies of weapons effects in Japan, the attenuation coefficients of material similar to that used in light-frame Japanese dwellings were measured. Also, one

shot indicated that readings from stations located on the side of a hill were essentially the same as those on level terrain at the same slant range from GZ.(Hurst 1958: 5-6, 19-23, 34,-36)

HARDTACK II

39.1 Oak Ridge National Laboratory (ORNL) obtained neutron and gamma-ray dose distribution in simulated Japanese type structures for correlation with data obtained by the Atomic Bomb Casualty Commission.(Reeves 1980: 100)

70.2 Measured gamma dose from the initial radiation, neutron induced activity, and fallout as a function of depth below the surface on 4 Area 7 shots. Initial radiation was measured from 4 stations on a line out to the limit of predicted significant radiation. Fallout was measured from 8 stations in Areas 7 and 9 which were located on a circle outside the limits of predicted significant radiation. (Reeves 1980: 96)

F. INSTRUMENTATION FOR CIVIL DEFENSE USES

Fa. Radiaiton Detection

UPSHOT-KNOTHOLE

22.2 Three new types of instruments were tested:

1) For yield estimates by measuring initial-gamma-radiation-dose in the very low milli-roentgen region;

2) Gamma dosimeters consisting of commercial and amateur films available on the common market; and

3) A survey meter for beta radiation consisting of a portable ionization chamber.

Radiological monitoring instruments were also evaluated.(Greene 1953: 3-4)

22.3 was to evaluate the experiences and findings of projects 22.1, 22.2, and 22.4 on 2 shots.(Corsbie 1953: 8)

29.1 By testing approximately 5,000 dosimeters, the accuracy and practicality of chemical versus film and other methods of gamma dosimetry were evaluated. Radiations of prompt and/or residual gammas and mixed neutron-gamma were examined. (Taplin 1953:3)

29.2 Preliminary work was conducted to determine whether or not germanium could be used as a dosimeter for fast neutrons. This work was continued and reported in TEAPOT 39.5.(Cassen 1955: 11-13)

29.4 To establish design requirements for radiation-detection instruments that are used in personnel monitoring, field measurements were made over periods of days and weeks of the gamma-ray energy spectrum from 3 tests.(Dahl 1954: 3)

TEAPOT

38.3 The capability to use commercial and amateur films as dosimeters could provide civil defense officials with a ready-made supply wherever film is sold. Exposure and evaluation of such readily available films were conducted.(Tolan 1957: 5,13; Peterson 1955: 65)

39.5 About 2500 improved germanium detectors and techniques for their use were tested at various distances, azimuths, and shieldings on 6 tests. The advantages of the germanium fast neutron dosimeters are: convenient use in large numbers, rapid recovery not required, provides a relatively permanent record of the measured levels, and "they respond to the full fast neutron spectrum in contradistinction to the response of threshold detectors."(Cassen 1955:11-13,25)

39.7 Part 1 Ionization chambers were used inside of lead hemispheres to further the development of this type of instrumentation for dosimetry of prompt radiation. Participation was on Wasp and Moth with a first design. Between Moth and Hornet, all chambers were rebuilt, then tested on Hornet, Bee, and Wasp Prime.(Rossi 1957: 5, 9,12, 20)

39.7 Part 2 was to be conducted by Los Alamos, but the report is unavailable.

PLUMBBOB
35.4 The beta-gamma exposure-rate ratio from fallout was investigated to: 1) Establish design criteria for survey instruments and 2) Evaluate existing instruments.(Tolan 1958: 3)

37.4 Improvements in the methodology and procedures for preparing germanium for the detectors were field tested on 5 shots.(Larson 1957: 3-4,14)

HARDTACK II
70.1 Preproduction models of instruments developed for aerial measurement of ground dose rate were evaluated. "Dose rates were measured by ground-survey teams along predetermined paths" and "compared with corresponding measurements taken by aerial-survey teams". The results of the evaluation were negative.(Martin 1959: 5)

Fb. Air Zero Locators
Air Zero Locators were instrumentation for determining yield and location of nuclear explosions. They were not developed to the stage of usefulness.

UPSHOT-KNOTHOLE
21.3 tested 4 models on Annie and Encore. (Goodwin 1953: 11)

TEAPOT
31.6 Seven types were tested on 3 tests as well as a pressure gauge to determine yield.(Gould 1955: 3-4, 11-2)

PLUMBBOB
31.1 Improved models were planned to be tested on 7 PLUMBBOB tests. (Corsbie 1957:11) The record for this project shows participation on only 1 test.

G. FALLOUT

Ga. Surveys

UPSHOT-KNOTHOLE

27.1 Fallout samples and measurements were taken after 5 tests "along existing trails and roads which crossed the various fallout patterns at distances greater than 10 miles from" GZ.(Rainey 1954: 3)

27.2 After each of 4 tests, radio-ecological surveys were made of the area adjacent to the NPG and up to 30 miles from the respective GZs. Samples were taken of native soils, plants, and animals. This activity was part of similar activities occurring intermittently since September 1951. "In areas repeatedly contaminated by radioactive fall-out during a two-year period, approximately 90 per cent of the residual radioactive material is associated with the surface inch of soil."(Lindberg 1954:3-4)

Starting with UPSHOT-KNOTHOLE and continuing during the next 3 operations, FCDA undertook a wide variety of projects regarding radiation and fallout detection, measurements, instrumentation, and surveys. Nearly 40% of the 158 civil defense projects conducted at the NTS during atmospheric testing were projects of this type. The importance and immensity of these undertakings was recognized by conducting project **29.3.** In this, mainly administrative, project the requirements of the CETG for dosimetry and radiation measurements were coordinated; various instruments were evaluated; and "instrument pools" were established for film badges, neutron threshold detectors and other instruments.(Corsbie 1953: 54)

TEAPOT

30.3 had two major objectives:

1) Instrumentation development:

- an aerial survey unit – measured gamma activity and accounted for the absorption of gamma radiation by the air between the ground and the aircraft. An accurate radar altimeter was also used.
- a portable gamma ray spectrometer – that measured spectra on the ground and in the air simultaneously, and
- a beta survey unit – determined the beta to gamma dosage ratios

2) Compilation of radiation characteristics of fallout:

- focused on sodium-24 and other short-lived neutron-induced isotopes as making a large contribution to the total activity.(LeVine 1955 :3-4,9,42)

37.2 For six tower shots, instrumentation was fielded at arcs of approximately 20, 40, 80, and 160 miles from GZ. Fall-out patterns were delineated by: survey methods; surface contamination levels and particle size distributions were determined; airborne radioactivity concentrations were obtained; and solubilities of fall-out and airborne activities were determined. One result was that "more than 90 percent of the fall-out radioactivity is separable by magnet." (Baurmash 1958: 5-6,18,35,82)

38.1 Aerial, automotive, and ground monitoring surveys were conducted in the fall-out paths after Apple 1 and 2 to evaluate and correlate data and methods. The attenuation factors of automobiles and airplanes was determined as was the response time of various instruments. Eight survey patterns that were accessible by foot, auto, and air were laid out. These patterns were in the shape of a cross with 4 legs of 1 mile each.(Rehm 1956 :5, 9-11)

38.4 was to refine information already available on the comparative intensities of radiation in various portions of houses in areas where significant fallout had taken place. Two houses of 31.1 were located in the region of probable fallout from CUE – the redesigned frame house and the two-story masonry house. Telemetering equipment was to be placed in the basement and first and second floors of the houses by Program 30. Detailed surveys of gamma radiation were to be made after the houses could be safely entered. Also, 2 trailer-coach mobile homes of project 36.1 were to be located in the direction of probable fallout and monitored in the same way.(Corsbie 1955: 66)

<u>PLUMBBOB</u>

32.2 was to test the calibration and utility of 2 types of scintillation detectors used with a radio altimeter for determining radiation levels on the ground. Ground and aircraft readings were to be compared, and 3 shots were planned.(Corsbie 1957:31)

32.4 Measurements were made at different times after Shasta on the radiation field near the surface and to heights of about 50 feet. Comparisons were also made of fallout particles resulting from Diablo, a tower shot, and Priscilla, a balloon shot. The iron from the shot tower, which became included into the fireball, caused a significant increase in the amount of gamma activity deposited in the local fallout. Several prototype collecting instruments were also evaluated.(Schuert 1959: 5,15)

35.2 When entry into the fallout area was permitted, radiation measurements were to be made on structures, roads, and natural surfaces. Flushing, sweeping, and earth moving decontamination procedures were to be undertaken and radiation levels re-measured on 3 shots. Vehicles with sand bags and/or dirt placed on their floors were also to be evaluated as emergency personnel carriers.(Corsbie 1957: 33)

35.3 Following a shot, simultaneous aerial, automotive, and ground surveys were to be conducted on 3 shots in fallout areas and correlated. Developmental models of monitoring equipment were to be evaluated. TOA of fallout, maximum intensity, and accumulated dose were to be determined at fixed stations.(Corsbie 1957: 34)

36.4 Similar to TEAPOT 38.1.(Rehm 1961: 5)

37.1, 37.2, 37.2a, 37.3, and 37.6 A radiometric survey provided greatly increased detail, accuracy, and distance information of fallout patterns. Isodose rate and time-of-arrival contour maps were obtained for seven tower and four balloon shots. The predominant particle size of fallout was determined on several arcs for each fallout pattern.(Larson 1966: 5)

HARDTACK II

37 was to use aerial surveys to construct iso-intensity maps and to re-sample previously established biological collection areas. Scheduling and yields prohibited data acquisition on most shots, but data was obtained from Quay.(Reeves 1980: 100)

Gb. Telemetering

UPSHOT-KNOTHOLE

28.1 To save manpower and reduce the personnel hazard attendant to fallout measurements, a telemetering system for off-site measurements of fall-out and associated phenomena: wind velocity, wind direction, temperature, etc. was field tested.(Johnson 1953: 11)

TEAPOT

30.1 "--unattended, automatic, continuously recording gamma-ray monitors were placed in 28 towns in populated areas adjacent to the" NTS.(LeVine 1956: 3-4)

30.2 "A gamma-radiation telemetering system was utilized to measure fall-out levels at the " NTS from near GZ "out to, and including, an area bounded by" Reno, NV; Salt Lake City, UT; Kingman, AZ; and Baker, CA. (Johnson 1956: 3-4)

PLUMBBOB

39.9 See above, Part II Chapter 3.Technical Area Ca, PLUMBBOB Projects 30.6 and 30.7.

Gc. Exposure of Objects to Fallout Fields

PLUMBBOB

32.1 Two reinforced Butler buildings were constructed and exposed to fallout from shots Daiblo, at 10,000', and Shasta, at 18,000'. After Shasta, because of sloping topography and near-by excavations for construction, another similar structure was erected at a location favorable to shot Whitney. Instead of using Whitney, Fitzeau was used which was over 10 miles away from both structures. The resulting dose rates and fallout deposition inside and outside the structures were measured with various instruments and techniques. Protection factors and roof and ground contributions to the total dose rates at points within the structures were determined from the measurements.(Breslin 1962: 5)

35.1 Many fallout dose measurements had been made in the past, but none were performed under geometric conditions of sufficient simplicity to permit comparison with theoretical calculations. This project measured the penetration of fallout radiation into concrete slabs in a geometry suitable for calculations. An area 200 yards in diameter was first cleared and leveled. Seven 3.15" thick aluminum reinforced concrete slabs 4' square were stacked and placed in a pit. The slabs were cast with a port through which a detector could be inserted. Twenty feet from the pit was a steel tower with 3 detectors at heights of 3 and 9 feet above ground to measure radiation emanating from fallout on the ground. (This would represent the "input" for the penetration calculations. The "output" of the calculations would be compared to the records taken by the detectors.) Ten feet from the pit was an underground vault

containing electronics for the tower and pit detectors. The pit was 2000 yards from GZ of shot A and 4000 yards from GZ of shot B, which are unidentified*.(Titus 1959: 5, 9, 11, 18,20)[*Footnote: Some reports of the 1950s did not mention the names of the shots. This was probably because the author(s) wanted to keep the report unclassified.]

38.1-I Packaging materials, wholesale or bulk containers, and retail containers were exposed along an arc approximately 25 miles from Priscilla GZ. Exposure stations were approximately 2 miles apart on this arc. The locations for the exposures were determined within 1 hr of shot time and were based on the best estimates for the path of the fallout cloud.

Eighteen types of packaging material were exposed such as mylar, Saran wrap, aluminum foil, paper bagging, cotton cloth, burlap, etc.. Wholesale or Bulk Containers were exposed with their contents: burlap, coffee and beans; paper sacks, pancake mix and flour; muslin sacks, bran; and cardboard containers, oatmeal. Retail containers included: cardboard, polyethylene, glass, milk carton, etc. The stations were instrumented with background radioactivity recorders, gummed paper, and plastic pellets.

"It was found that the plastics and paper tested were adequate for preventing contamination of food therein"—"burlap and cloth offered poor protection. Oily or dusty surfaces proved more retentive for fallout than clean ones." For cleaning, "wet or dry cloth wiping seemed to be the most effective, with detergent washing and brushing next."(Leininger 1958: 5, 9-11)

38.1-II This project was closely associated with the above 2 projects in terms of personnel and support, but exposures were only at ¼ and ½ mile, from GZ, Two FCDA stockpile items were exposed: bottles containing dextrose-saline solution and anticoagulant. Both items were "bottled under vacuum; however the vacuum was relieved on half the bottles –". Twenty cartons were exposed at ¼ mile, and 20 at ½ mile. At each station, 10 cartons were place in each of 2 parallel 20' long trenches (to simulate a storage depot) that were perpendicular to the direction of GZ. The cartons were placed in the trenches with the necks of the bottles pointing in 3 directions: toward GZ, away for GZ, and up.(Laug 1958: 5-6, 11-13)

38.2 Wheat, snapped corn, cotton seed, soya beans, potatoes, and dried fruits were exposed at 5 identical exposures stations about 2-miles apart at about 25 miles from Piscilla GZ. Again, final "fix" was at about -1hour, and the instrumentation was the same as 38.1-I.

It was found that water washing of "dried fruits, soya beans, and cotton seed was relatively ineffective in removing fallout contamination. Husks prevented the contamination of ears of corn. Other such interesting results are given in the reference.(Lenininger 1958: 5, 9-10)

Gd. Plant and Animal Studies in Fallout Fields

<u>TEAPOT</u>

37.1 A study of the factors that influence the biological fate and persistence of fallout in areas adjacent to the NTS was conducted . Factors included: plants, animals, characteristics of the fallout (e.g., particle size, type of material), and the fractionation of fallout material as it may vary with distance from GZ.(Lindberg 1959:5,15)

HARDTACK II

39.9a was a continuing project initiated during PLUMBBOB and was operational during the interium between PLUMBBOB and HARDTACK II. Its objective was to appraise the extent of nuclear effects on vegetation at the test site.(Reeves 1980: 97)

H. PHOTOGRAPHY

The only identified civil defense photography projects were on TEAPOT and PLUMBBOB. However, UPSHOT-KNOTHOLE and HARDTACK II certainly had photographic coverage of civil defense projects, but they were possibly conducted by AFSWP or AEC. References are generally not available for photography projects.

TEAPOT

39.4a Technical Photography (Documentary); **39.4b** Technical Photography (High Speed – Blast Biology); and **39.4c** Technical Photography (High Speed, Physical Phenomena, and Structural Response)

PLUMBBOB

39.4 Technical Photography – EG&G

I. TRAINING EXERCISES

UPSHOT-KNOTHOLE

22.1 FCDA's training exercises started with this project on UPSHOT-KNOTHOLE that met between 22 April and 5 May and had 14 participants who were in technical professions and members of CD organizations across the nation.(Lamoureux 1953: 3-4, 14, 19-20)

TEAPOT

38.2 On April 13, a group of 24 nuclear technology professionals with clearances arrived at NTS for a 3 week exercise that extended into 4 weeks. This exercise was more detailed and "hands-on" than the UPSHOT-KNOTHOLE 22.1 exercise had been.(Goeke 1955:3, 9-20)

38.5 On April 21, 1955, 49 persons with state and local responsibilities in radiological defense departed CA in a "controlled convoy" to participate in Apple 2 which ws known as Operation CUE by FCDA. They arrived at Overton NV (about 55 miles NE of Las Vegas), and checked into accommodations. The 49 men formed into 3 groups: Monitor, Control-center, and Mobile-laboratory. The next days, they spent getting ready for CUE: conducting monitoring and communications exercises, monitoring a contaminated area south of Alamo (about 85 miles north of Las Vegas), and collecting and analyzing soil, plant, and air samples from contaminated area. On May 2, they just went home. After a number of delays, Apple 2 was shot on May 5.(Rainey 1955: 3-15)

PLUMBBOB

Two groups of combined state and local radiological defense personnel attended unclassified training sessions. Group 1 (**36.1**), consisting of 40 trainees, convened during June 17-28; and Group 2 (**36.2**) consisting of 16 trainees convened during August 8 to September 3. Both groups conducted foot, vehicle, and aerial surveys of fallout fields from earlier PLUMBBOB shots and observed current shots. In addition, Group 2 participated in Program 35 activities which included: decontamination procedures, monitoring techniques, and instrumentation evaluation.(Killian 1958: 5, 9-12, 18-24)

36.3 A motion picture was produced which demonstrated the techniques used in monitoring fallout levels.(Lobdell 1957:9)

36.5 Preshot indoctrination regarding the operation was to be conducted. After a shot, one group was to man a fixed command unit, and another monitor contaminated areas using various techniques. Duties would then be rotated. Mock field operations were to be conducted on 3 that would last until about D+4.(Corsbie 1957: 41)

38.3 A field training course was conducted in areas contaminated by radioactive fallout. Information was acquired on methods for measuring and monitoring fallout with portable and laboratory equipment and methods of decontamination were studied and conducted in actual participation in the shots of PLUMBBOB. There were both dry runs and actual runs under shot conditions. (McConnell 1959: 5)

ACRONYMS

A-Bomb	Atomic Bomb
ACC	Army Chemical Corps, also sometimes used for Army Chemical Center
ACWL	Army Chemical Warfare Laboratories
AEC	Atomic Energy Commission
AFB	Air Force Base
AFCRC	Air Force Cambridge Research Center, also known as AFCRL
AFOAT	Air Force Office for Atomic Testing
AFSWC	Air Force Special Weapons Command (or Center)
AFSWP	Armed Forces Special Weapons Project
AMC	Air Material Command
ARDC	Air Research and Development Command located in Inglewood, CA
ARF	Armour Research Foundation
ASW	Anti-Submarine Weapon
BRL	Ballistics Research Laboratories
CBR	Chemical, Biological, and Radiological
CD	Civil Defense (compact discs had not yet been invented)
CEREL	Civil Engineering Research and Engineering Laboratory - Navy
CETG	Civil Effects Test Group, a test group under the Test Director during operations TEAPOT and PLUMBBOB
CP	Control Point
CRL	Chemical and Radiological Laboratories
DASA	Defense Atomic Support Agency
DMA	Division of Military Applications (of the Atomic Energy Commission)
DNA	Defense Nuclear Agency
DOB	Depth Of Burial – the depth below the surface of the ground at which an object is placed and subsequently covered, usually with earth or earth-like material(s), back to ground level.
DoD	Department of Defense
DTMB	David Taylor Model Basin
DTRA	Defense Threat Reduction Agency
DTRIAC	Defense Threat Reduction Information Analysis Center (Kirtland AFB, Albuquerque, NM)
EG&G	Edgerton, Germeshausen, and Grier
EM	Electromagnetic, waves or signals, radio signals are an example
ERDL	Engineer Research and Development Laboratories, Army
ESL	Evans Signal Laboratory
FCDA	Federal Civil Defense Agency
GPS	Global Positioning Satellite
GZ	Ground Zero
HE	High Explosive (a chemical explosive)
HOB	Height of Burst, the distance above (or below) the ground surface at which the detonation occurs.
IBDA	Indirect Bomb Damage Assessment
ICBM	Intercontinental Ballistic Missile

ID	Inside Diameter
IFC	Intermittent Fallout Collector
IGZ	Intended Ground Zero
kt	kilotons
LANL	Los Alamos National Laboratory
LASL	Los Alamos Scientific Laboratory
LORAN	Long Range Aids to Navigation
LVT	Landing Vehicle, Tracked
MIT	Massachusetts Institute of Technology
MSL	Mean Sea Level
NBA	Navy Bureau of Aeronautics
NBS	National Bureau of Standards
NEL	Naval Electronics Laboratories
nm	nautical miles
NML	Naval Material Laboratory
NOL	Naval Ordanance Laboratory
NPG*	Nevada Proving Grounds
NRDL	Naval Radiological Defense Laboratory, San Francisco, CA
NRL	Naval Research Laboratory
NPG	Nevada Proving Ground
NTS*	Nevada Test Site
NWE	Nuclear Weapons Effects
OCDM	Office of Civil and Defense Mobilization {Prior to July 1, 1958, the civil part of OCDM was known as the Federal Civil Defense Agency (FCDA) and the defense part of OCDM was known as the Office of Defense Mobilization (ODM).}
OCE	Office, Chief of Engineers (Army)
OD	Outside diameter
ODM	Office of Defense Mobilization
ORNL	Oak Ridge National Laboratory
Pmax	Pressure maximum, Peak Overpressure
POL	Petroleum, Oil, and Lubricants
psi	pounds per square inch, sometimes written as lbs/in^2
Radef	Radiological Defense
RADIAC	RAdiation Detection Indication And Computation – Instrumentation
SAC	Strategic Air Command of US Air Force
SCEL	Signal Corps Engineering Laboratories, Fort Monmouth, NJ
SNPC	Service National de la Protection Civile, of France
SRI	Stanfod Research Institute
TAC	Tactical Air Command of the US Air Force
TNT	Trinitrotoluene, a chemical high explosive. The complete explosion of a 1 kt mass of TNT is called 1 kt of energy and is equivalent to 10^{12} calories of energy.
TOA	Time of Arrival
UCLA	University of California at Los Angeles
UCRL	University of California Radiation Laboratory, at Berkeley and Livermore
USAEC	United States Atomic Energy Commision, a term sometimes used instead of just AEC

USA	United States Army
USAF	United States Air Force
VLP	Very Low Pressure
WADC	Wright Air Development Center
WRAMC	Walter Reed Army Medical Center
wrt	with respect to
WT	Weapons Test – This acronym is used for Weapons Test reports that were made for each of the projects conducted during an operation.
WWII	World War II

[*Footnote: The history of the names for the nuclear testing area in Nevada can be summarized as follows:

- On July 6, 1951, the Nevada site was officially named the Nevada Test Site (NTS) by the AEC. Before that time it had no official name, but Nevada Test Site was one of the names frequently encountered. NTS was the name during BUSTER-JANGLE.

- In early 1952, the name was changed to the Nevada Proving Grounds (NPG). NPG was the name used during TUMBLER-SNAPPER and UPSHOT-KNOTHOLE. Many scientists in the testing community were not pleased and argued that it was a location for *testing* **not** for *proving.*

- The name Nevada Test Site (NTS) was adopted by the AEC on the last day of 1954. This name stuck throughout the remainder of the nuclear testing period and is still used today.]

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